# BYCATCH IN THE SOUTHEAST SHRIMP TRAWL FISHERY

## A DATA SUMMARY REPORT

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This report completes SFA Task N-10.03
(Bycatch/Incidental Harvest Research - Collection of Information on Incidental Shrimp Harvest)

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# INTRODUCTION

In February 1992, a joint commercial/government research program was initiated between the National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) and the Gulf and South Atlantic Fisheries Development Foundation, Inc. (Foundation) to collect species-specific bycatch data to characterize catch rates by number and weight taken by the shrimp fishery during commercial operations in the U.S. Gulf of Mexico and along the southeast Atlantic coast of the Untied States. The goals of this joint research program were to: 1) update bycatch estimates temporally and spatially, 2) manage and maintain bycatch characterization data sets, 3) analyze bycatch characterization data on the temporal and spatial catch rates of finfish and shrimp, 4) provide data to estimate total bycatch of selected species for stock assessment analysis, 5) develop and evaluate various bycatch reduction devices (BRD), 6) manage and maintain bycatch reduction device data sets, and 7) provide summary data set files and summaries to independent researchers for analyses. This research effort has and will continue to provide essential data to Southeast Regional Office (SERO), Gulf and South Atlantic Fishery Management Councils, fish and wildlife departments of Gulf and south Atlantic states, associations of commercial shrimpers and recreational fishermen, and legislators and elected officials at all levels of government. The intent of this particular paper is to provide a general overview of the results from this research program. These summary data will be used, along with more detailed analyses, to prepare a Southeast Shrimp Trawl Fishery Bycatch Report to Congress by October 1998. The Congressional Report will contain such items as comprehensive program review, stocks assessment results, economic analyses, and ecological model information.

This summary report is presented in four sections, with corresponding graphs and tables in appendices at the conclusion of each section. The Table of Contents provides a listing of all the figures in each appendix. The text in each section is brief, since this report is only to present a basic overview of the data. The four sections include: 1) general overview, 2) bycatch characterization summary, 3) bycatch reduction device testing and evaluation summary, and 4) literature references (reports, publications, and products) as a result of the southeast shrimp trawl bycatch program research efforts.

# SECTION 1: GENERAL OVERVIEW

The sampling design used in this research effort followed the guidelines as set forth in the Research Plan Addressing Finfish Bycatch in the Gulf of Mexico and South Atlantic Shrimp Fisheries, prepared by the Foundation, under the direction of a Steering Committee composed of individuals representing industry, environmental, state, and Federal interests (Hoar, et al., 1992). The intent of the sampling design was to survey the shrimp fishery during commercial operation and not to simply establish a research survey study of the bycatch or the finfish populations.

Over the past five years (February 1992 through December 1996) a total of 4,215 sea days of sampling effort have been achieved by NMFS observers (1,405 days) and non-NMFS observers (2,810 days) in the Gulf of Mexico and along the east coast of the United States. Most of the effort occurred in waters off Texas (1,219 days) and Louisiana (1,096 days), followed by the Atlantic (920 days), Florida (841 days), and Alabama-Mississippi (139 days). These sea days were accomplished during 604 trips, varying in length from 1 to 54 days. From these sea days, bycatch data have been collected from 5,695 individual tows, with several hundred different species being documented from the trawls.

# SECTION 2: CHARACTERIZATION SUMMARY

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In the characterization analyses, stratification cells were identified using three seasons (Pre-Summer: January through April, Summer: May through August, and Post-Summer: September through December), seven locations (Atlantic <34°N latitude, Atlantic between 30°-34°N latitude, Atlantic >30°N latitude, West Florida, Alabama-Mississippi, Louisiana, and Texas), and two depth zones in the Gulf of Mexico (nearshore, ≤10 fm; and offshore, >10 fm). In the Atlantic <34°N area only the inshore area was sampled, while in the other two Atlantic areas only the offshore was sampled in this research. The sample unit in each cell consisted of a single subsample from a trawl haul.

## METHODS

NMFS-trained observers were used to collect the trawl haul subsamples and record the data from the fishery. A subsample was obtained from a randomly selected net after each tow. The data collected consisted of tow weight, species composition, species abundance, species weight, and length measurements by species groups. Preliminary research tows indicated that a subsample of 13 kg per towing hour was adequate to ensure that most species taken in the catch were adequately represented in the subsample. A detailed description of the onboard sampling procedures is contained in the NMFS Bycatch Characterization Sampling Protocol (Galveston Laboratory, 1992). All observers, whether funded by NMFS, the Foundation, or other agencies, were required to collect data following this protocol.

## RESULTS

**APPENDIX I** contains summary graphs for the southeast Atlantic and Gulf of Mexico catch (weight) per unit effort results. The bar charts show an average catch comparison for commercial shrimp species (SHRIMP), non-commercial shrimp crustaceans (CRUSTACEA), non-crustacean invertebrates (INVERTEBRATES), and finfish (FISH), for the various seasons and areas. The pie charts show the ten most dominant species for the various areas.

When all tows collected in the southeast Atlantic (east coast of the United States) were combined for analysis, the statistics revealed that on the average about 27 kg of organisms per hour are taken during trawling operations. Analysis of the composition of the organisms showed that about 51% of the catch by weight is composed of finfish, 18% by commercial shrimp species (brown shrimp, *Penaeus aztecus;* white shrimp, *P. setiferus;* pink shrimp, *P. duorarum;* seabobs, *Xiphopenaeus kroyeri;* sugar/blood shrimp, *Trachypenaeus* spp; and rock shrimp, *Sicyonia brevirostris*), 13% by non-commercial shrimp crustaceans, and 18% by non-crustacean invertebrates.

Shrimp trawl catch per hour averages for each of the different seasons were examined during the analysis. The pre-summer season had the lowest overall catch rates at 12 kg per hour, while the summer and post-summer seasons had very similar catch rates at around 30 kg per hour. Finfish catch rates always comprised more than 44% of the catch, while shrimp catch rates were approximately 15% to 18% in the summer and post-summer periods, respectively, but 37% in the pre-summer season.

Shrimp trawl catch per hour averages for each of the different locations were also reviewed during the analysis. The northern area (<34°N) had the highest overall catch rates (37 kg per hour), while the other two areas were similar in catch rates at around 25 kg per hour. On the average, about 8 kg of finfish are taken as bycatch for every one kg of commercial shrimp harvested in a trawl in the northern area (<34°N), with about 2.5 to 3 kg of finfish taken as bycatch for every one kg of commercial shrimp harvested in the middle (30°-34°N) and southern (>30°N) Atlantic areas.

In the Atlantic northern area (<34°N) blue crab (*Callinectes spidus*) made up 19% of the average weight of a typical trawl, followed by pink shrimp at 16%, and spot (*Leiostomus xanthurus*) at 12%. In the Atlantic middle area (30°-34°N) cannonball jellyfish (*Stomolophus meleagris*) made up the greatest average weight at 11%, followed by both Atlantic menhaden (*Brevoortia tyrannus*) and white shrimp at 10%. In the Atlantic southern area (>30°N) brown shrimp made up the greatest percentage of the catch in a typical trawl at 16%, followed by star drum (*Stellifer lanceolatus*) at 14%, and southern kingfish (*Menticirrhus anericanus*) at 9%.

When all tows collected in the Gulf of Mexico were combined for analysis, the statistics revealed that on the average about 28 kg of organisms per hour are taken during trawling operations. Analysis of the composition of the organisms showed that about 67% of the catch by weight is composed of finfish, 16% by commercial shrimp species (brown shrimp, white shrimp, pink shrimp, seabobs, sugar/blood shrimp, and rock shrimp), 13% by non-commercial shrimp crustaceans, and 4% by non-crustacean invertebrates.

Shrimp trawl catch per hour averages for each of the different seasons were examined during the analysis. The pre-summer season had the lowest overall catch rates at 20 kg per hour, while the summer and post-summer seasons had very similar catch rates at above 30 kg per hour. Finfish catch rates were above 60% of the catch, while shrimp catch rates were around 15% to 18% in the post-summer and summer periods, respectively, and 16% in the pre-summer season.

Shrimp trawl catch per hour averages for each of the different locations and depth zones was also examined during the analysis. In all but one case (Alabama/Mississippi) the offshore zone had a lower catch rate than the nearshore area for the same location. The Alabama-Mississippi area had the highest overall combined (nearshore + offshore) catch rates, while the Louisiana nearshore area had the greatest catch rate for a single area. Offshore Florida had the lowest single area catch rate. In each area, the lowest catch rates were for non-crustacean invertebrates, followed by non-shrimp crustaceans and commercial shrimp, with finfish comprising the highest catch rates. On the average, about 4 kg of finfish are taken as bycatch for every one kg of commercial shrimp harvested in the trawl in the Gulf of Mexico.

In the Florida nearshore area pink shrimp made up 18% of the average weight of a typical trawl, followed by iridescent swimming crab (*Portunus* *gibbesii*) at 9%, and leopard searobin (*Prionotus scitulus*) at 6%. In the Florida offshore area the pink shrimp made up the greatest average weight at 19% followed by blotched swimming crab (*Portunus spinimanus*) at 8%, and shoal flounder (*Syacium gunteri*) at 7%. In the Alabama-Mississippi nearshore area the Atlantic croaker (*Micropogonias undulatus*) made up the greatest percentage of the catch in a typical trawl at 34%, followed by the brown shrimp at 11%, and the sand seatrout (*Cynoscion arenarius*) at 7%. In the Alabama-Mississippi offshore area the longspine porgy (*Stenotomus caprinus*) represented the species with the greatest overall average weight percentage in the catch at 16%, followed by inshore lizardfish (*Synodus foetens*) at 5%, and Atlantic croaker at 5%.

In Louisiana, the Atlantic croaker represented the greatest percentage of the nearshore catch at 19%, with white shrimp next at 12%, followed by Gulf menhaden (*Brevoortia patronus*) at 9%. In the offshore waters, longspine porgy was greatest at 15%, followed by inshore lizardfish at 10% and Atlantic croaker at 9%. The Texas area was very similar to Louisiana. The nearshore catch was dominated by Atlantic croaker at 14%, followed by Gulf butterfish (*Peprilus burti*) at 13% and brown shrimp at 7%. In the offshore area the longspine porgy represented the greatest component of the catch at 16%, followed by brown shrimp at 16%, and Atlantic croaker at 9%. It can be seen from the data the Atlantic croaker is the bycatch species that is represented the most frequently in the nearshore trawls for most areas, while the longspine porgy typically dominated the offshore trawls.

**APPENDIX II** contains summary graphs for the southeastern Atlantic and Gulf of Mexico catch (number) per unit effort results. The bar charts show an average catch comparison for commercial shrimp species (SHRIMP), non-commercial shrimp crustaceans (CRUSTACEA), non-crustacean invertebrates

(INVERTEBRATES), and finfish (FISH), for the various seasons and areas. The pie charts show the ten most dominant species for the various areas.

When all tows collected in the south Atlantic (east coast of the United States) were combined for analysis, the statistics revealed that on the average about 1450 organisms per hour are taken during trawling operations. Analysis of the composition of the organisms showed that about 54% of the catch by number is composed of finfish, 23% by commercial shrimp species (brown shrimp, white shrimp, pink shrimp, seabobs, sugar/blood shrimp, and rock shrimp), 12% by non-commercial shrimp crustaceans, and 11% by non-crustacean invertebrates.

Shrimp trawl catch per hour averages for each of the different seasons were examined during the analysis. The pre-summer season had the lowest overall catch rates with 850 individual organisms per hour, followed by the summer period with around 1350 organisms per hour. The greatest rates were in the post-summer period with 1800 organisms per hour taken in the trawls. Finfish catch rates always comprised more than 44% of the catch, while shrimp catch rates were 17% to 26% in the post-summer and summer periods, respectively, and 11% in the pre-summer season.

Shrimp trawl catch per hour averages for each of the different locations were also examined during the analysis. The middle area (30°-34°N) had the highest overall catch rates (1550 individual organisms per hour), while the other two areas were similar in catch rates with approximately 1050 organisms per hour. On the average, 1.3 finfish are taken as bycatch for every one commercial shrimp harvested in a trawl in the northern area (<34°N), with about 2.2 to 2.8 finfish taken as bycatch for every one commercial shrimp harvested in the southern (>30°N) and middle (30°-34°N) Atlantic areas, respectively.

In the Atlantic northern area (<34°N) the pink shrimp made up 23% of the average by number from a typical trawl, followed by spot at 20%, and the brown shrimp at 14%. In the Atlantic middle area (30°-34°N) star drum made up the greatest average number at 16%, followed by both brown and white shrimp at 10%. In the Atlantic southern area (>30°N) the brown shrimp made up the greatest percentage of the catch from a typical trawl at 22%, followed by the star drum at 21%, and the northern searobin (*Prionotus carolinus*) at 7%.

When all tows collected in the Gulf of Mexico were combined for analysis, the statistics revealed that on the average, about 1350 organisms per hour are taken during trawling operations. Analysis of the composition of the organisms showed that about 50% of the catch by number is composed of finfish, 29% by commercial shrimp species (brown shrimp, white shrimp, pink shrimp, seabobs, sugar/blood shrimp, and rock shrimp), 17% by non-commercial shrimp crustaceans, and 4% by non-crustacean invertebrates.

Shrimp trawl catch per hour averages for each of the different seasons were examined during the analysis. The pre-summer season had the lowest overall catch rates at 800 individual organisms per hour, followed by the post-summer period at around 1300 organisms per hour. The greatest rates were in the summer period at around 2100 organisms per hour taken in the trawls. Finfish catch rates were always above 46% of the catch, while shrimp catch rates were about 29% to 30% in the summer and post-summer periods, respectively, and 28% in the pre-summer season.

Shrimp trawl catch per hour averages for each of the different locations and depth zones was also analyzed. In all but one case (Alabama/Mississippi) the offshore zone had a lower catch rate than the nearshore area for the same location. The Alabama-Mississippi area had the highest overall combined (nearshore + offshore) catch rates, while the Alabama-Mississippi offshore area had the greatest catch rate for a single area. Offshore Florida had the lowest single area catch rate. In each area the lowest catch rates were for non-crustacean invertebrates, followed by non-shrimp crustaceans, then commercial shrimp, and finally finfish with the highest catch rates. On the average, about 1.8 finfish are taken as bycatch for every one commercial shrimp harvested in the trawl.

In the Florida nearshore area, pink shrimp made up 27% of the average number of a typical trawl, followed by the iridescent swimming crab at 12%, and the leopard searobin at 11%. In the Florida offshore area, pink shrimp made up the greatest average number at 28%, followed by the longspine swimming crab (*Portunus spinicarpus*) at 9%, and the shoal flounder (*Syacium gunteri*) at 7%. In the Alabama-Mississippi nearshore area, Atlantic croaker made up the greatest percentage of the catch by number in a typical trawl at 18%, followed by the brown shrimp at 17%, and the lesser blue crab (*Callinectes similis*) at 10%. In the Alabama-Mississippi offshore area the longspine porgy represented the species with the greatest overall average number percentage in the catch at 19%, followed by the longspine swimming crab at 10%, and the sugar/blood shrimp at 7%.

In Louisiana, Atlantic croaker represented the greatest percentage of the nearshore catch by number at 17%, with white shrimp next at 14%, followed by brown shrimp at 12%. In the offshore waters longspine porgy was greatest at 18%, followed by sugar/blood shrimp at 10%, and the longspine swimming crab at 8%. The Texas area was again quite similar to Louisiana. The nearshore catch was dominated by the Gulf butterfish at 13%, followed by the longspine porgy at 12%, and the Atlantic croaker at 11%. In the offshore area the longspine porgy represented the greatest component of the catch by number at 20%, followed by the brown shrimp at 14%, and the sugar/blood shrimp at 10%.

Although groundfish species makeup the majority of the bycatch taken in shrimp trawls, several species that represent major or even minor components of the total bycatch have received a great deal of attention because of their commercial and recreational importance, and the potential for significant impacts on their population abundance. Five species (2 dominant and 3 less dominant) from the Gulf of Mexico and five species (2 dominant and 3 less dominant) from the east coast of the United States area are presented in **APPENDIX III.** In the Gulf of Mexico the two dominant species included the Atlantic croaker and the longspine porgy, while the less dominant caught species included the king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*Scomberomorus maculatus*), and red snapper (*Lutjanus campechanus*). In the southeast Atlantic the two dominant species included the Atlantic croaker and the spot, while the less dominant caught species included the king mackerel, Spanish mackerel, and weakfish (*Cynoscion regalis*).

In the southeastern Atlantic, the Atlantic croaker had its highest catch rates by weight in the northern area (<34°N) at the end of 1993 and the beginning of 1994. A high catch rate also occurred in the post-summer 1993 period in the southern area (>30°N). Catch rates by numbers showed similar peaks to those noted above. The average size of Atlantic croaker in the southeastern Atlantic was 134 mm total length. The catch of spot by both weight and number was greatest in the northern area (<34°N) and less in the southern area (>30°N) . Summer and post-summer seasons seemed to have the highest rates. The average length of spot in the southeastern Atlantic was 110 mm total length. The catch of king mackerel by both weight and number was very low throughout the most areas. The greatest catch by weight (about 0.16 kg per hour) and number (about 0.6 individuals per hour) was during the post-summer 1992 period in the middle area (30°-34°N). The average length was 168 mm fork length. Spanish mackerel were more abundant than king mackerel, but still represented a less dominant caught species. Highest catch rates by both weight and number were in the northern area (<34°N) in the summer 1992 period and by weight in the summer 1993 period in the southern area (>30°N). Average size was 173 mm fork length. Weakfish catch by both weight and number was greatest in the northern area (<34°N) during the 1993 and 1994 periods, with post-summer or summer periods in the southern area (>30°N) also with high weight and number catch rates. Weakfish were also found in the trawls in the middle area (30°-34°N) with greatest weights in the pre-summer and summer periods. The average length of weakfish was 127 mm total length.

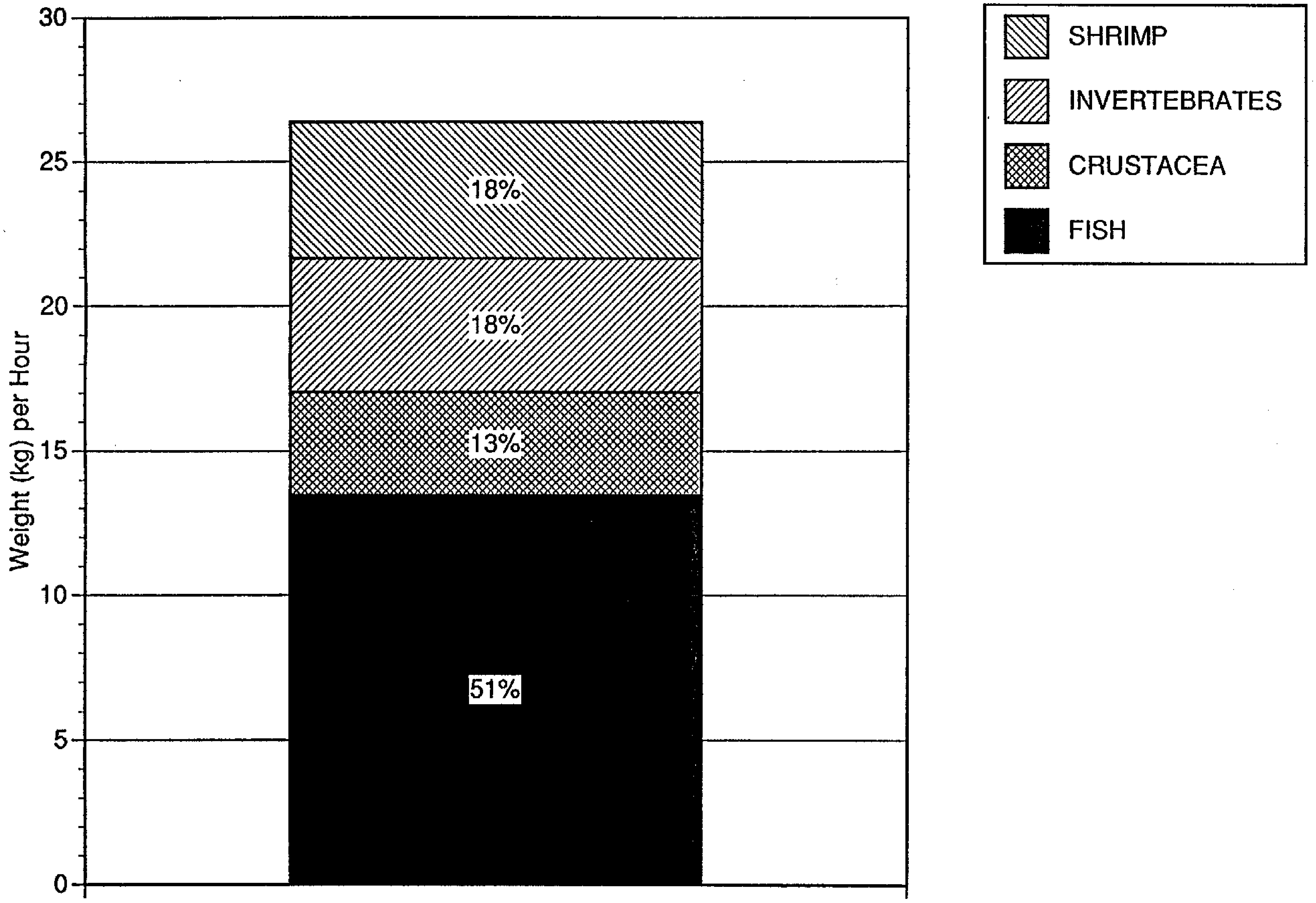
In the Gulf of Mexico, the Atlantic croaker had the highest catch rates by weight and in the nearshore area off Alabama-Mississippi and Louisiana. Average length was around 161 mm total length. Longspine porgy had its highest catch rates by both number and weight in the offshore waters of Alabama-Mississippi, Louisiana, and Texas. Two very large catch rates by weight were noted in the post-summer 1993 and summer 1994 periods off the Alabama-Mississippi area. Average size for longspine porgy in the Gulf of Mexico was only 90 mm fork length. The highest catch rates by weight for king mackerel have been observed in the Texas area, typically during the summer seasons nearshore and the post-summer seasons offshore. One very high catch rate by weight was noted in the nearshore area of Louisiana in the post-summer 1993 period. Average catch by number had several peaks, however, with none above about 6 individuals per hour. King mackerel had a average length of 230 mm fork length. Red snapper were rarely caught in the Florida and Alabama-Mississippi areas. Highest catch rates by both weight and number occurred in the offshore waters of Texas and Louisiana. Red snapper had a mean length of 117 mm fork length. Spanish mackerel had their highest catch rates by weight in the nearshore waters off Texas, Louisiana, and Alabama-Mississippi. A very high catch rate (for Spanish mackerel) was noted during the summer season in 1993 off Louisiana, but most values are below 0.5 kilograms per hour. Catch rates by number had similar trends to those noted for weight. Spanish mackerel had an average length of 205 mm fork length.

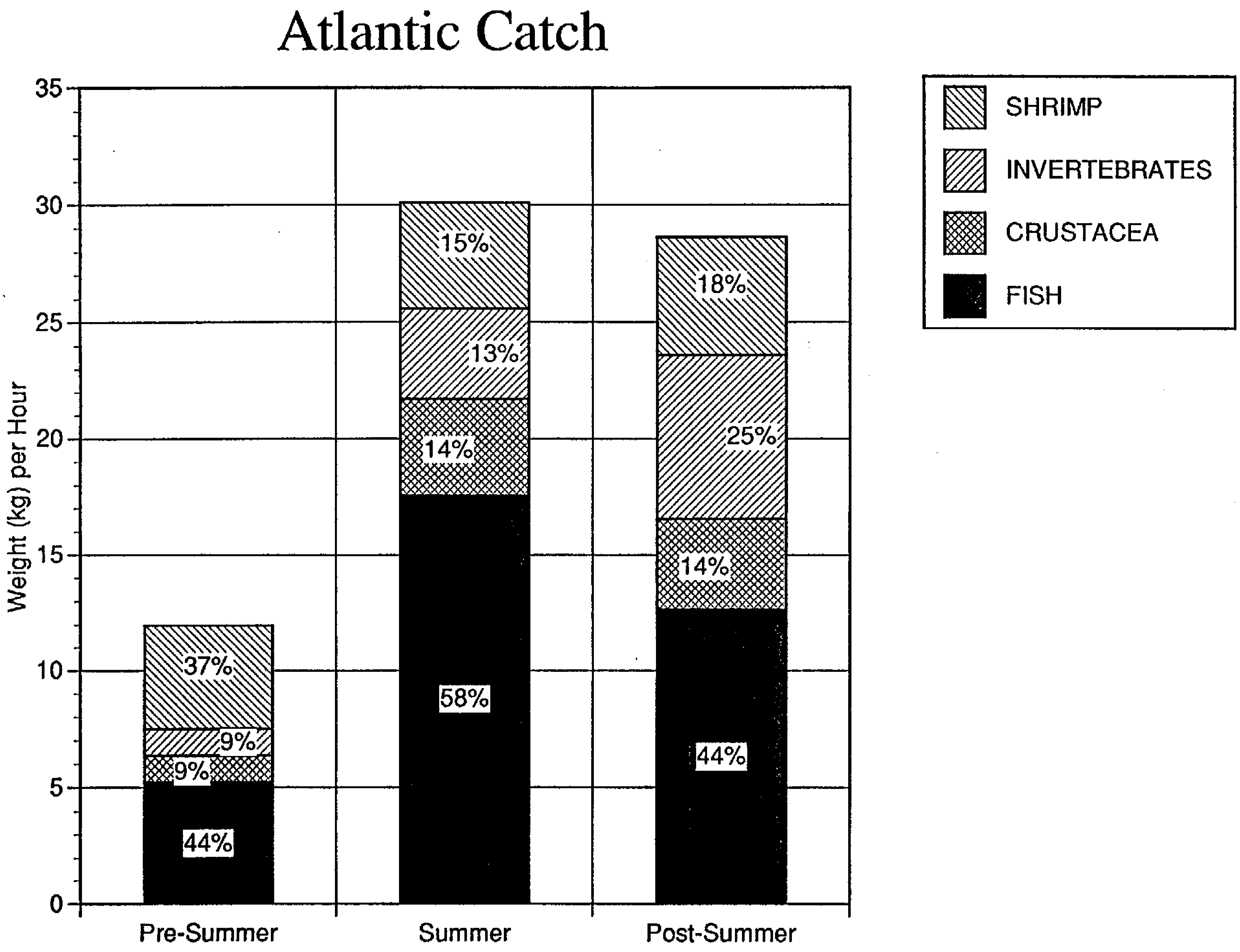
# SECTION 2: APPENDIX I

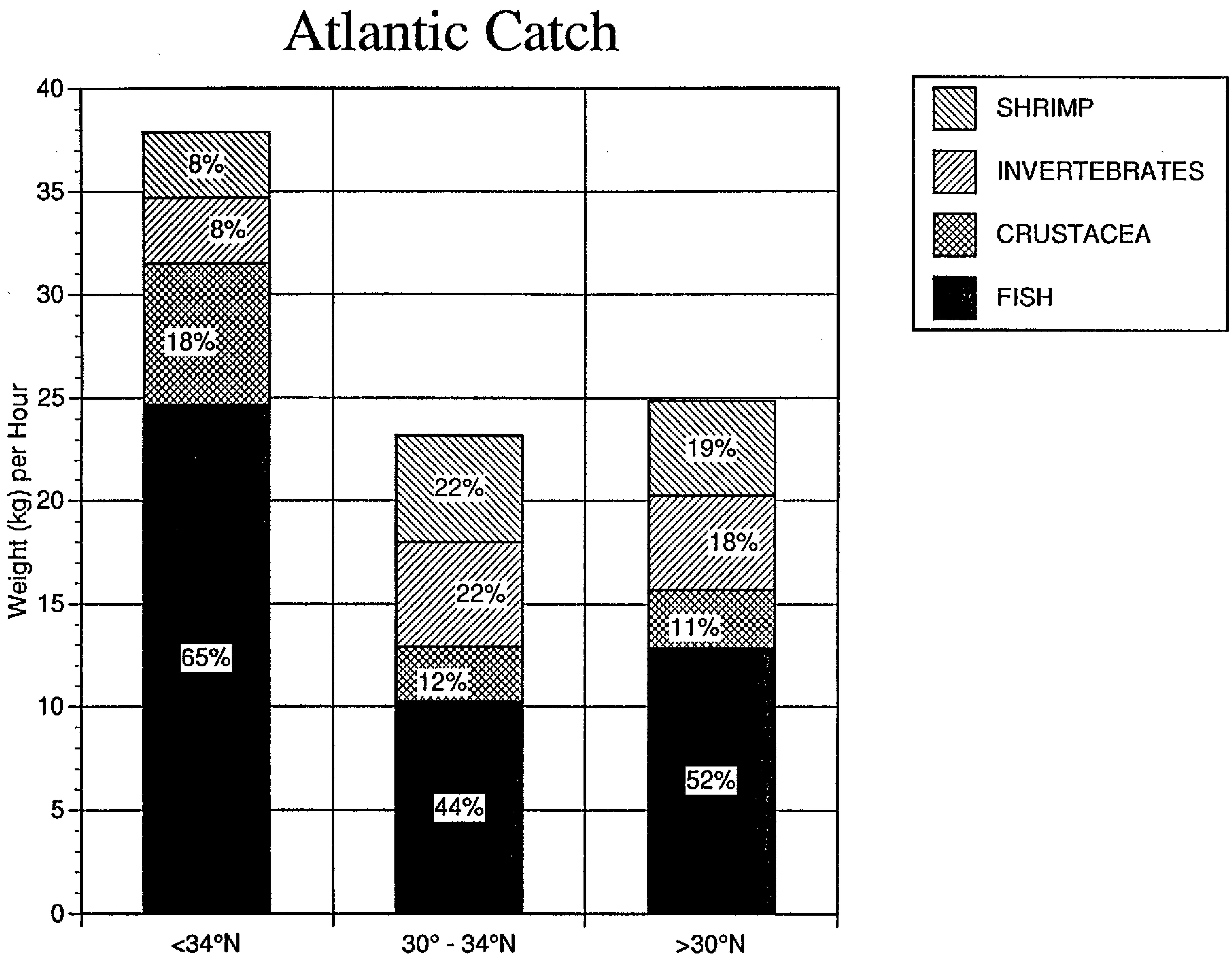
## SHRIMP CHARACTERIZATION

## CATCH (WEIGHT) PER UNIT EFFORT GRAPHS
## (SPECIES GROUPS)

# Atlantic Catch




Atlantic Catch
Weight (kg) per Hour
0
5
10
15
20
25
30
35
Pre-Summer
Summer
Post-Summer
44%
9%
9%
37%
58%
14%
13%
15%
44%
14%
25%
18%
SHRIMP
INVERTEBRATES
CRUSTACEA
FISH

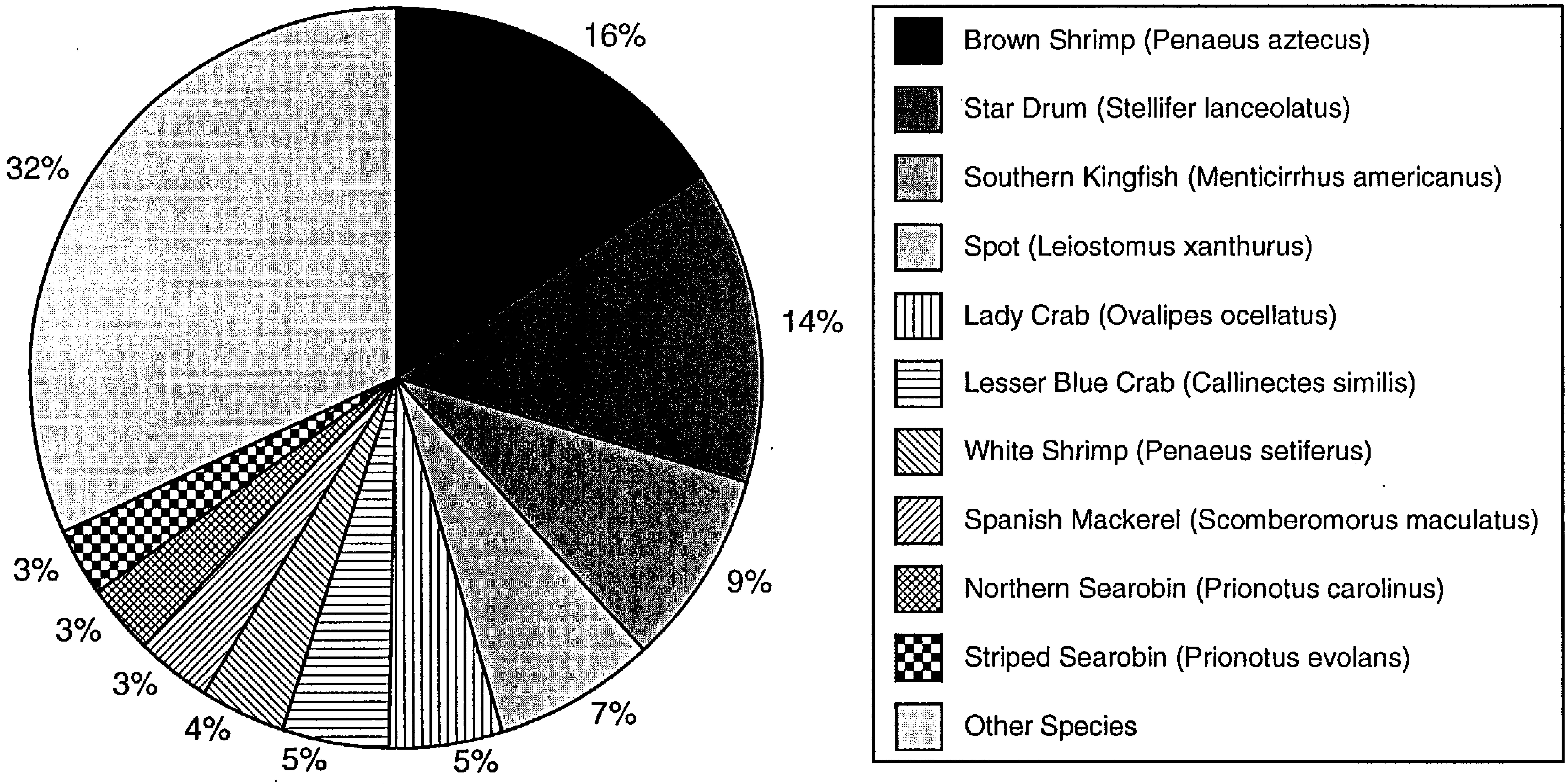


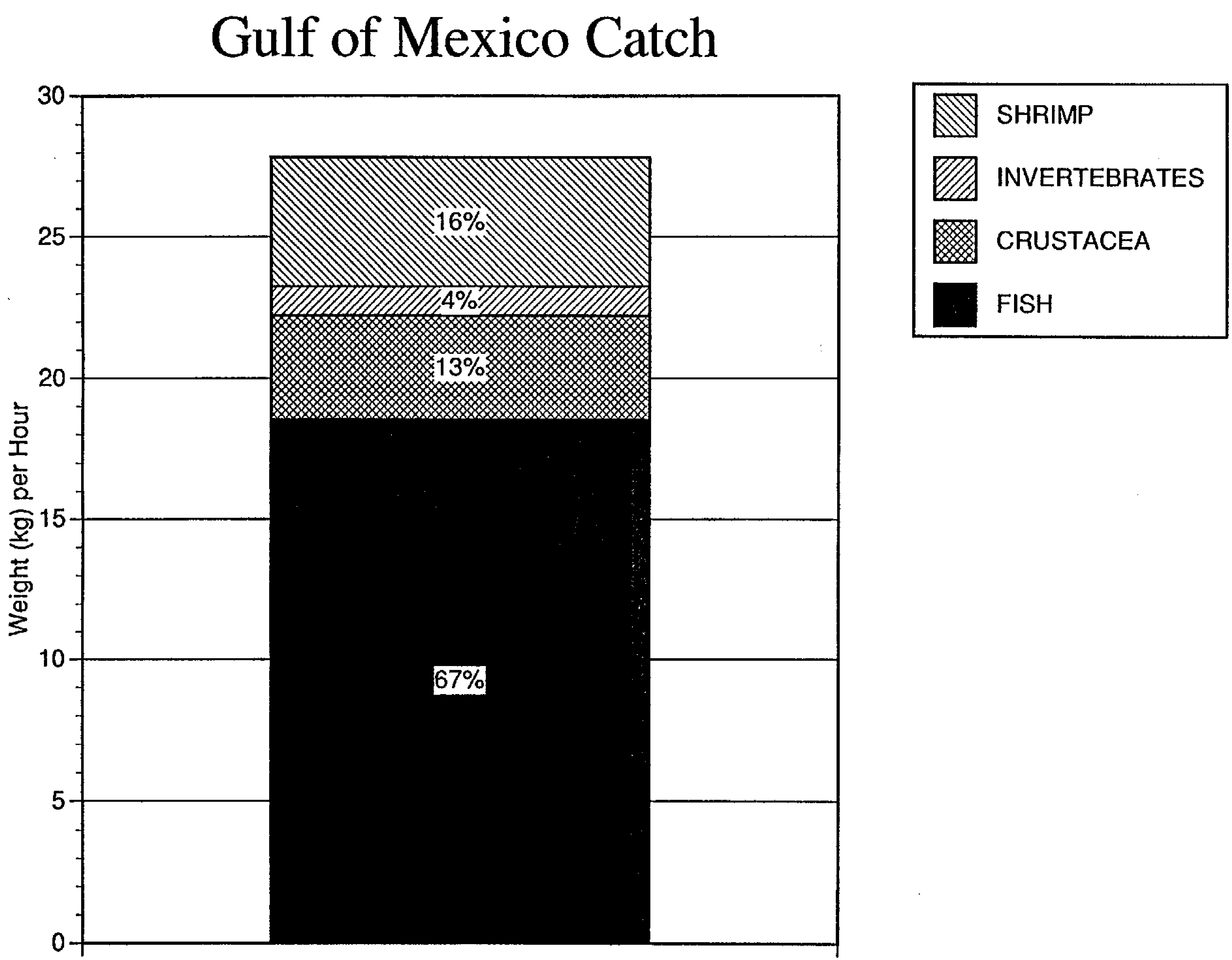
Atlantic Catch
Weight (kg) per Hour
0
5
10
15
20
25
30
35
40
<34°N
30° - 34°N
>30°N
8%
8%
18%
65%
22%
22%
12%
44%
19%
18%
11%
52%
SHRIMP
INVERTEBRATES
CRUSTACEA
FISH

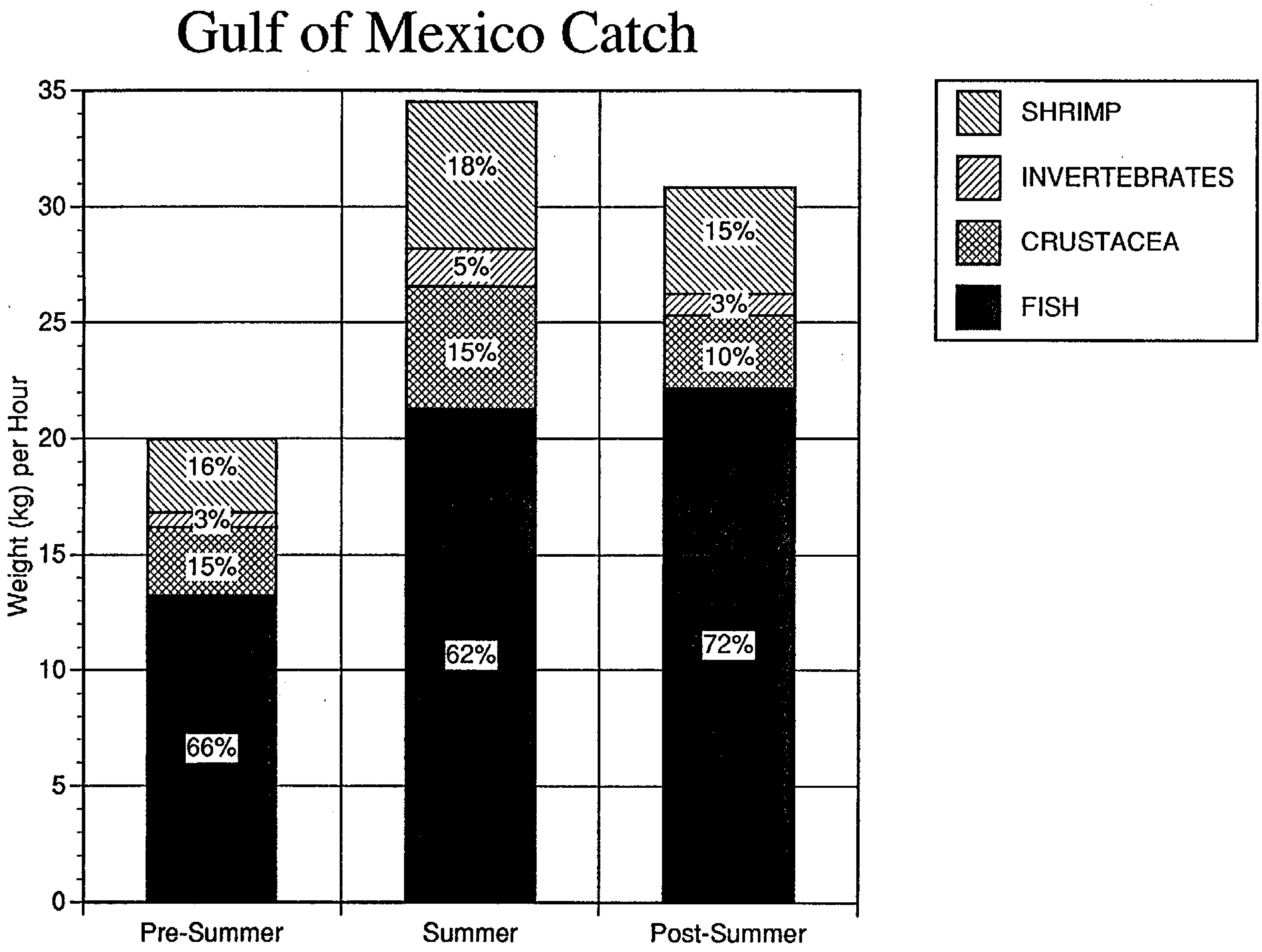
# Atlantic (>34°N) Weight (kg) per Hour

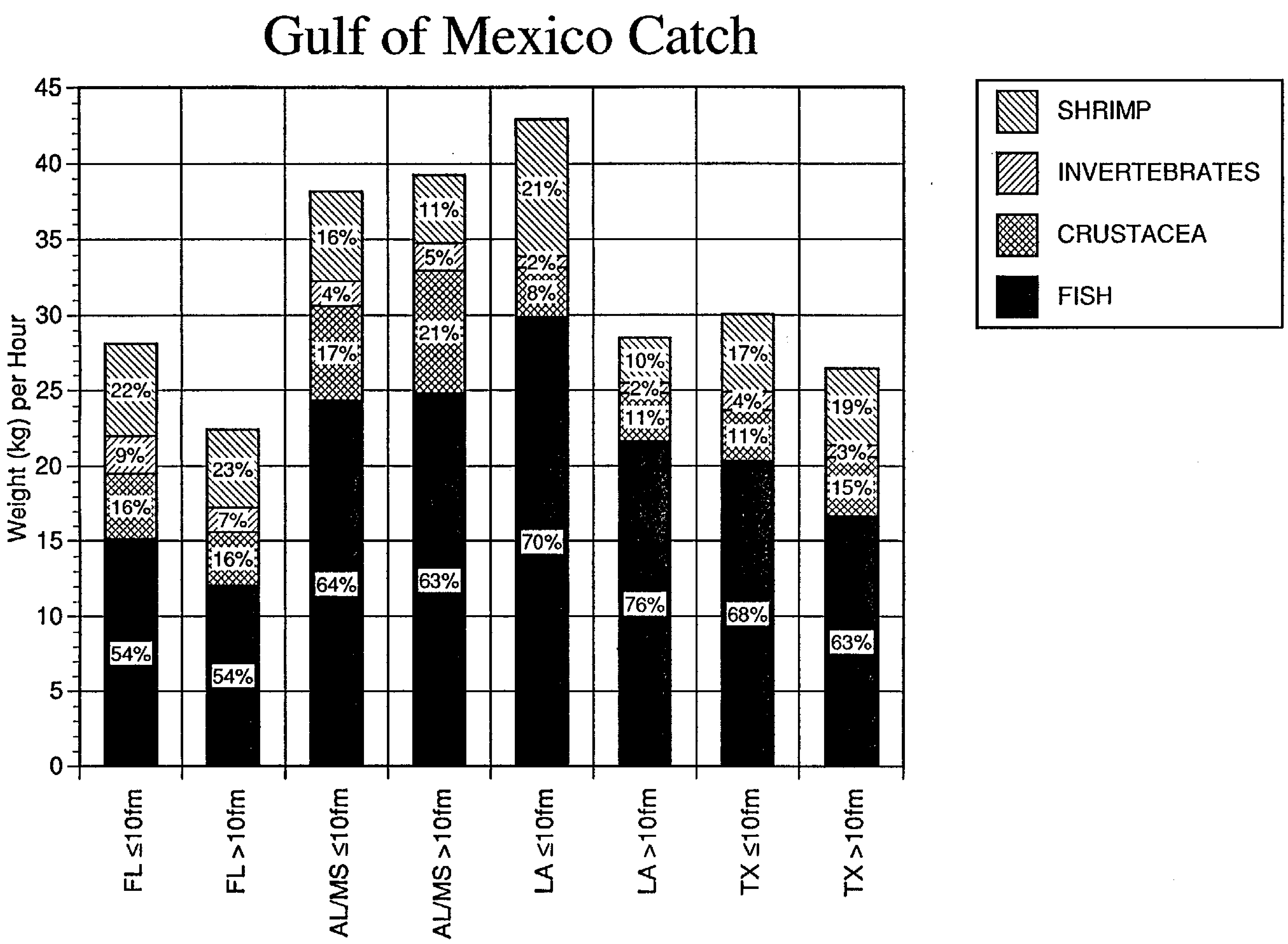

Atlantic (30°-34°N) Weight (kg) per Hour
11%
10%
10%
8%
7%
7%
6%
6%
5%
2%
28%
Cannonball Jellyfish (Stomolophus meleagris)
Atlantic Menhaden (Brevoortia tyrannus)
White Shrimp (Penaeus setiferus)
Spot (Leiostomus xanthurus)
Star Drum (Stellifer lanceolatus)
Jellyfish (Carybdeidae)
Brown Shrimp (Penaeus aztecus)
Atlantic Croaker (Micropogonias undulatus)
Southern Kingfish (Menticirrhus americanus)
Cutlassfish (Trichiurus lepturus)
Other Species

# Atlantic (<30°N) Weight (kg) per Hour




Gulf of Mexico Catch
Weight (kg) per Hour
0
5
10
15
20
25
30
16%
4%
13%
67%
SHRIMP
INVERTEBRATES
CRUSTACEA
FISH

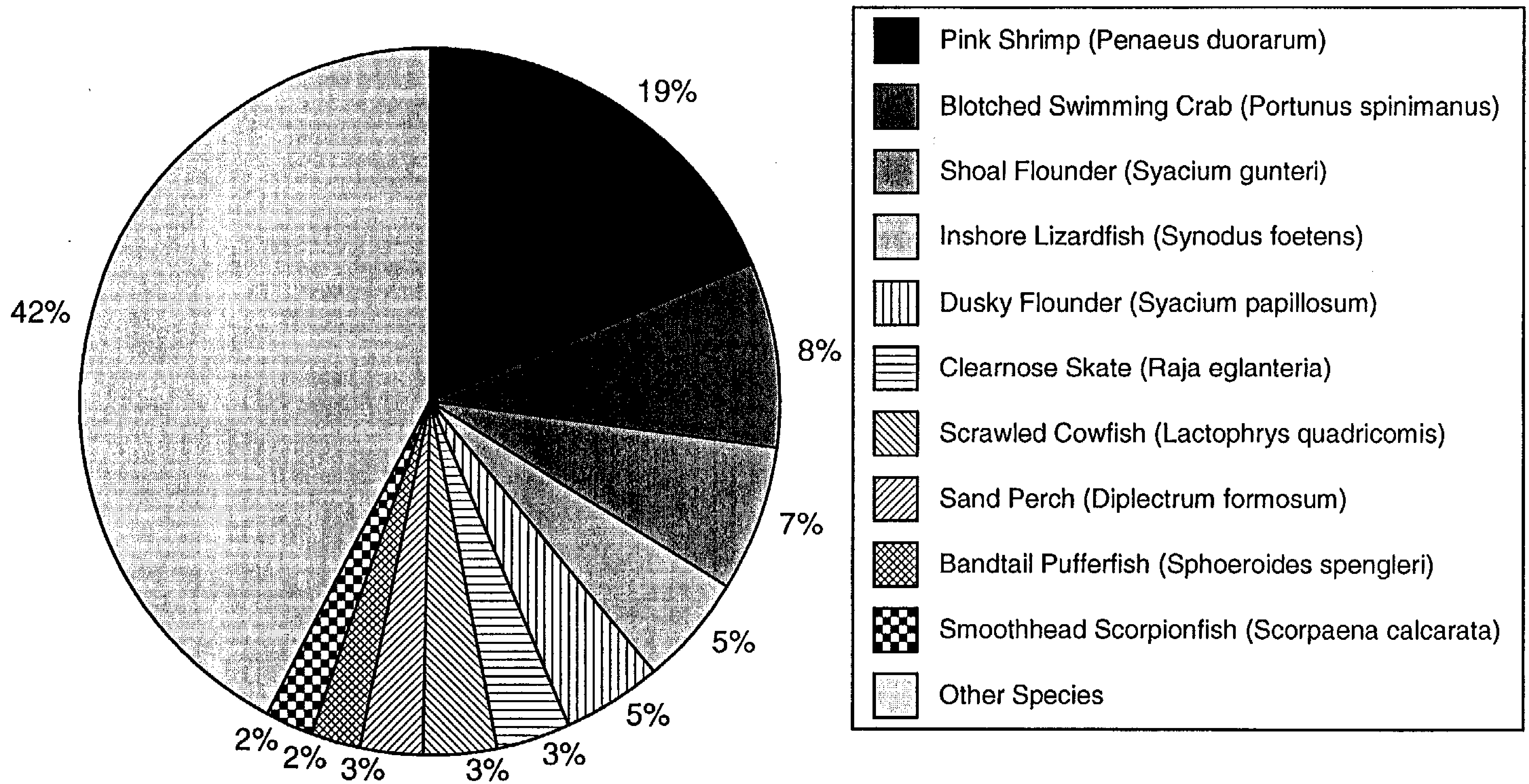

Gulf of Mexico Catch
Weight (kg) per Hour
35
30
25
20
15
10
5
0
Pre-Summer
Summer
Post-Summer
66%
15%
3%
16%
62%
15%
5%
18%
72%
10%
3%
15%
SHRIMP
INVERTEBRATES
CRUSTACEA
FISH



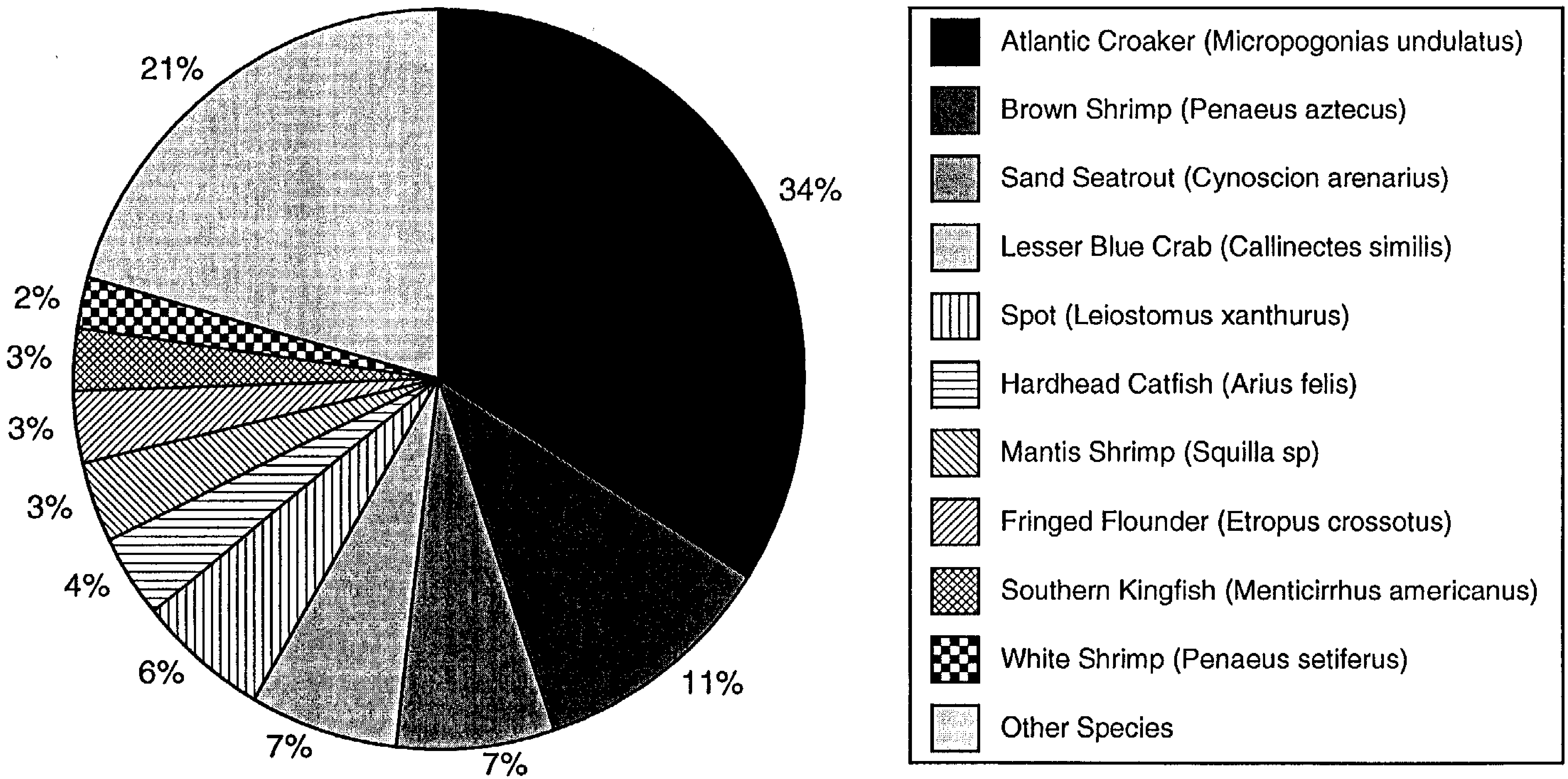
Gulf of Mexico Catch
Weight (kg) per Hour
45
40
35
30
25
20
15
10
5
0
SHRIMP
INVERTEBRATES
CRUSTACEA
FISH
FL ≤10fm
FL >10fm
AL/MS ≤10fm
AL/MS >10fm
LA ≤10fm
LA >10fm
TX ≤10fm
TX >10fm
22%
9%
16%
54%
23%
7%
16%
54%
16%
4%
17%
64%
11%
5%
21%
63%
21%
2%
8%
70%
10%
2%
11%
76%
17%
4%
11%
68%
19%
3%
15%
63%

# Florida (≤10fm) Weight (kg) per Hour

# Florida (>10fm) Weight (kg) per Hour

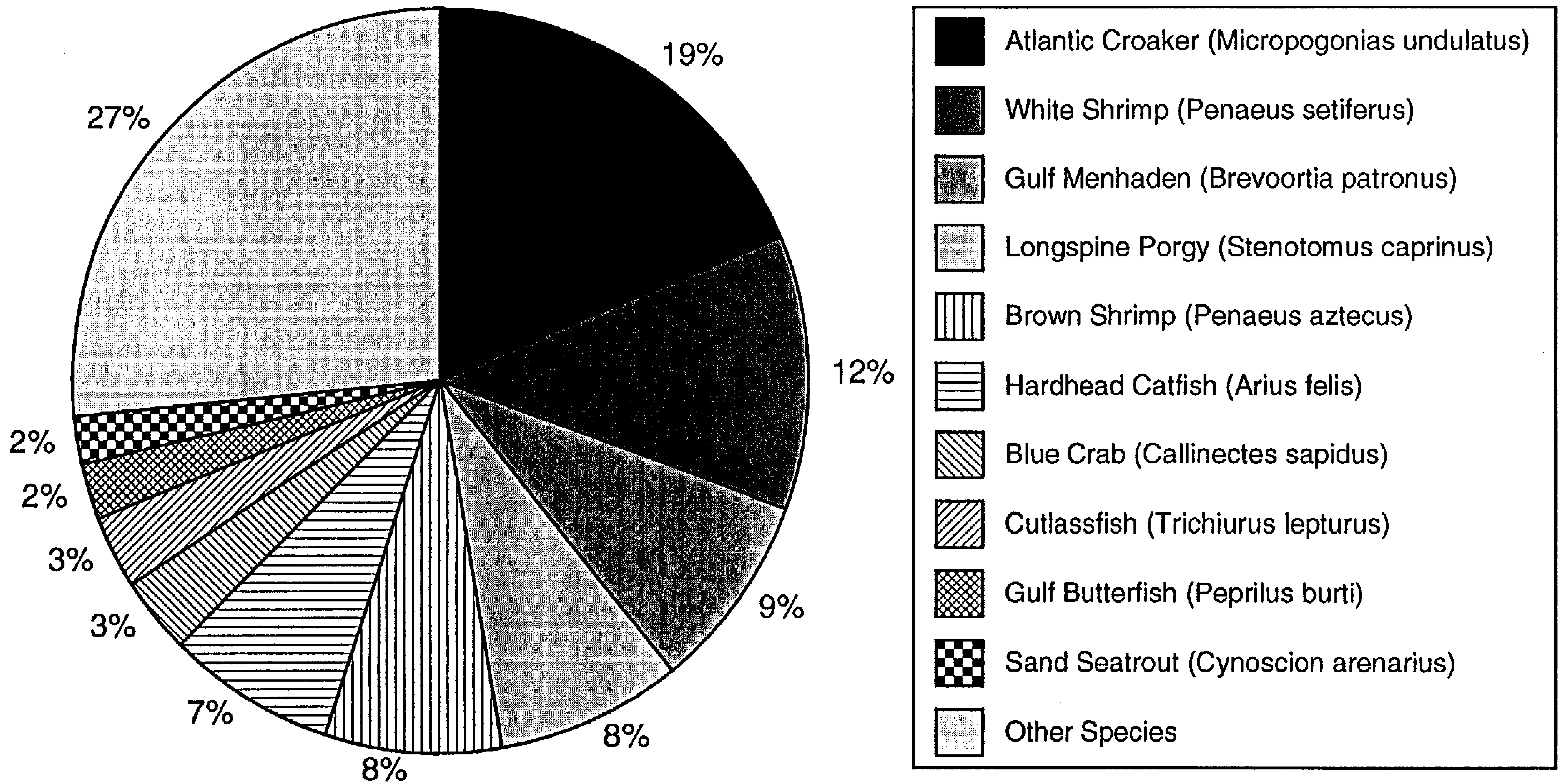


# AL/MS (≤10fm) Weight (kg) per Hour



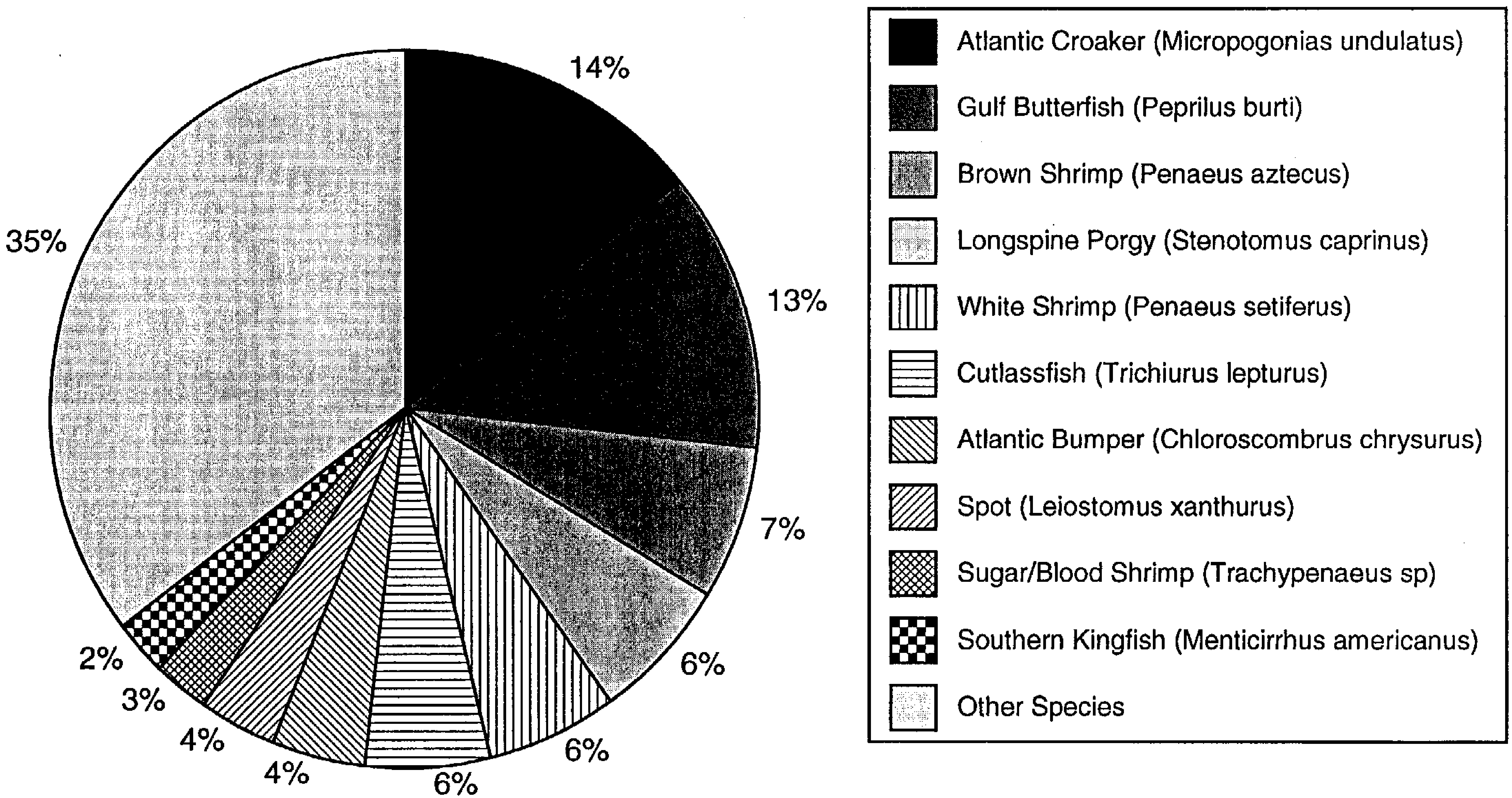
# AL/MS (>10fm) Weight (kg) per Hour

# Louisiana (≤10fm) Weight (kg) per Hour

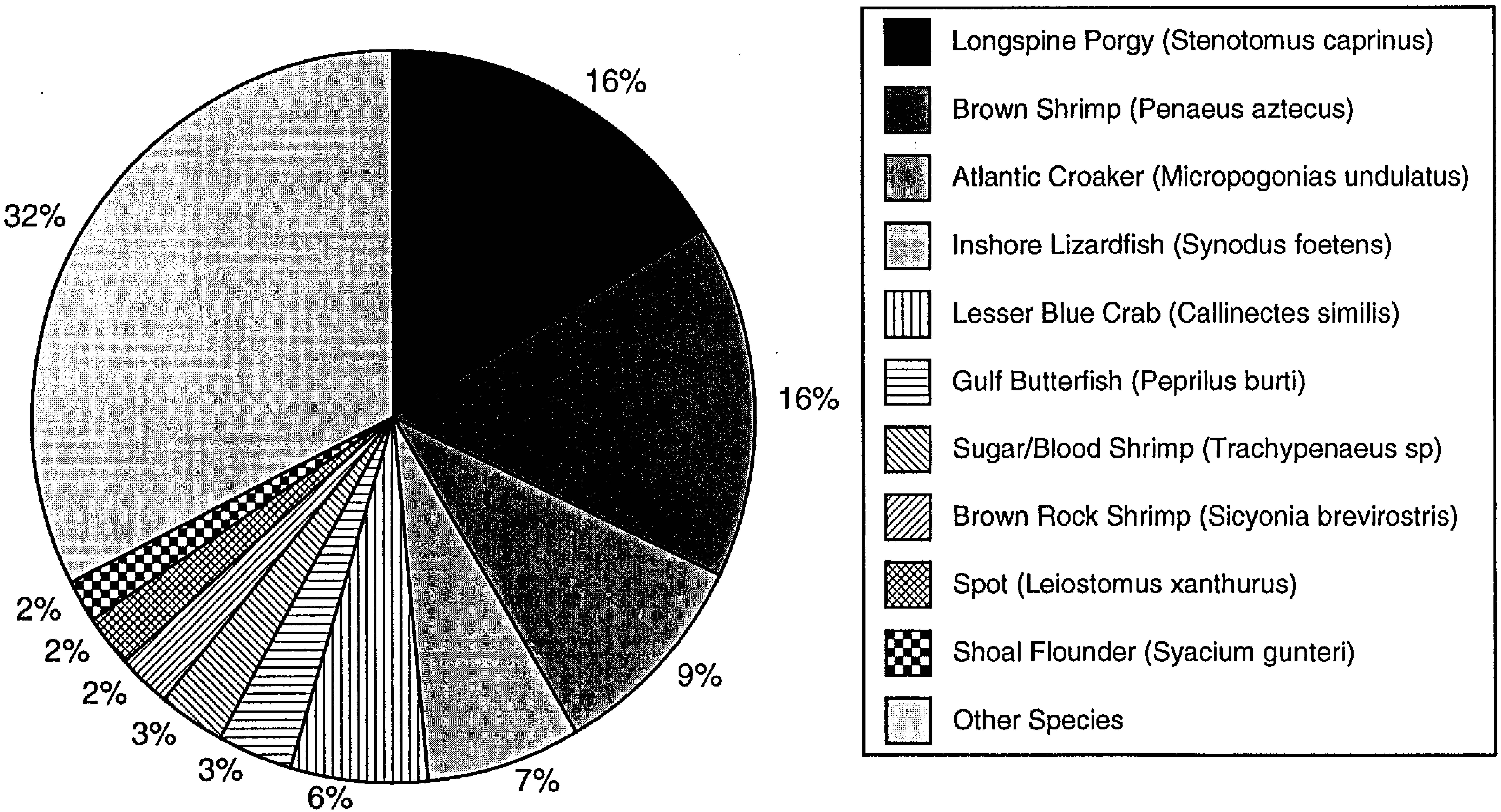


# Louisiana (>10fm) Weight (kg) per Hour

# Texas (≤10fm) Weight (kg) per Hour



# Texas (>10fm) Weight (kg) per Hour

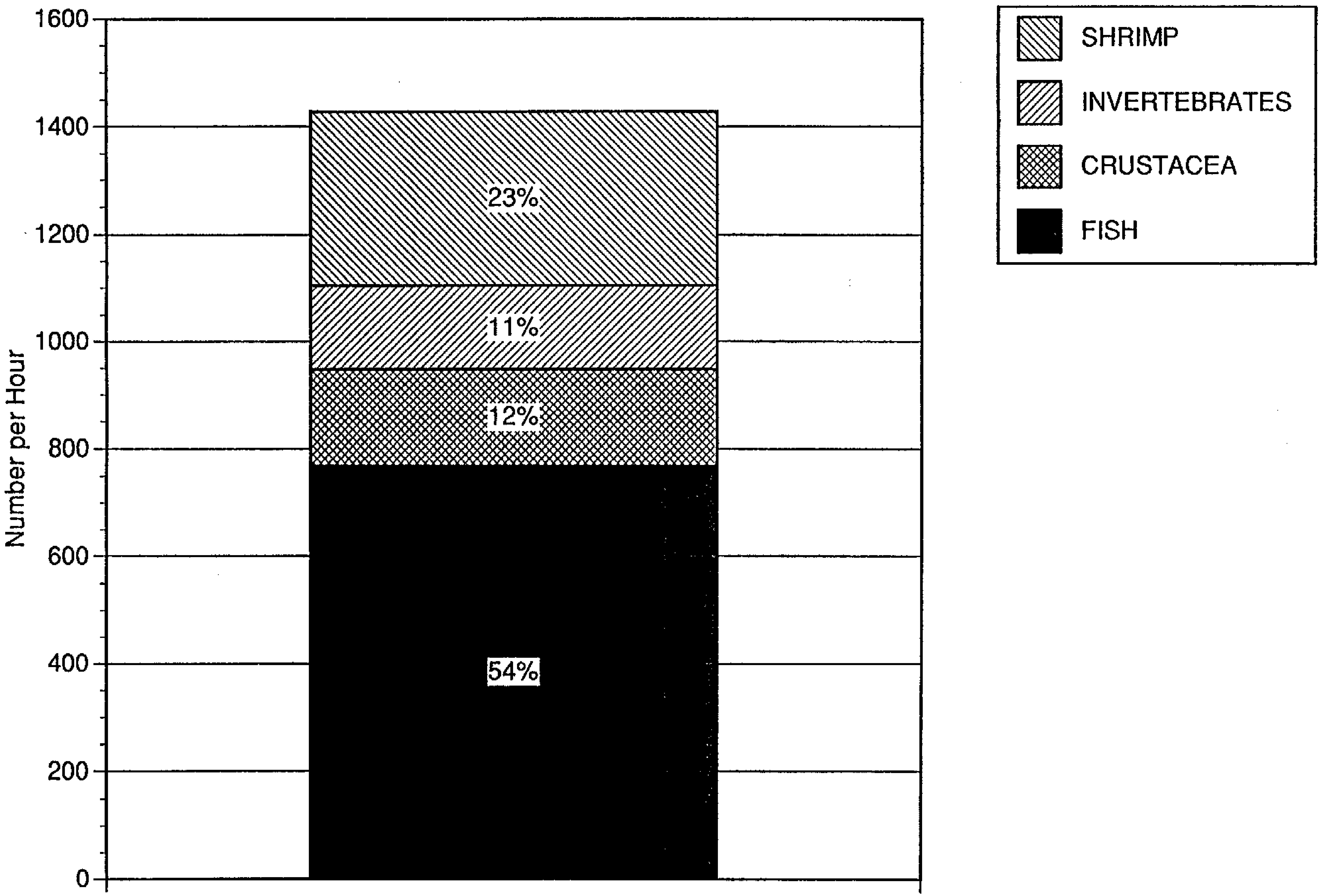


# SECTION 2: APPENDIX II

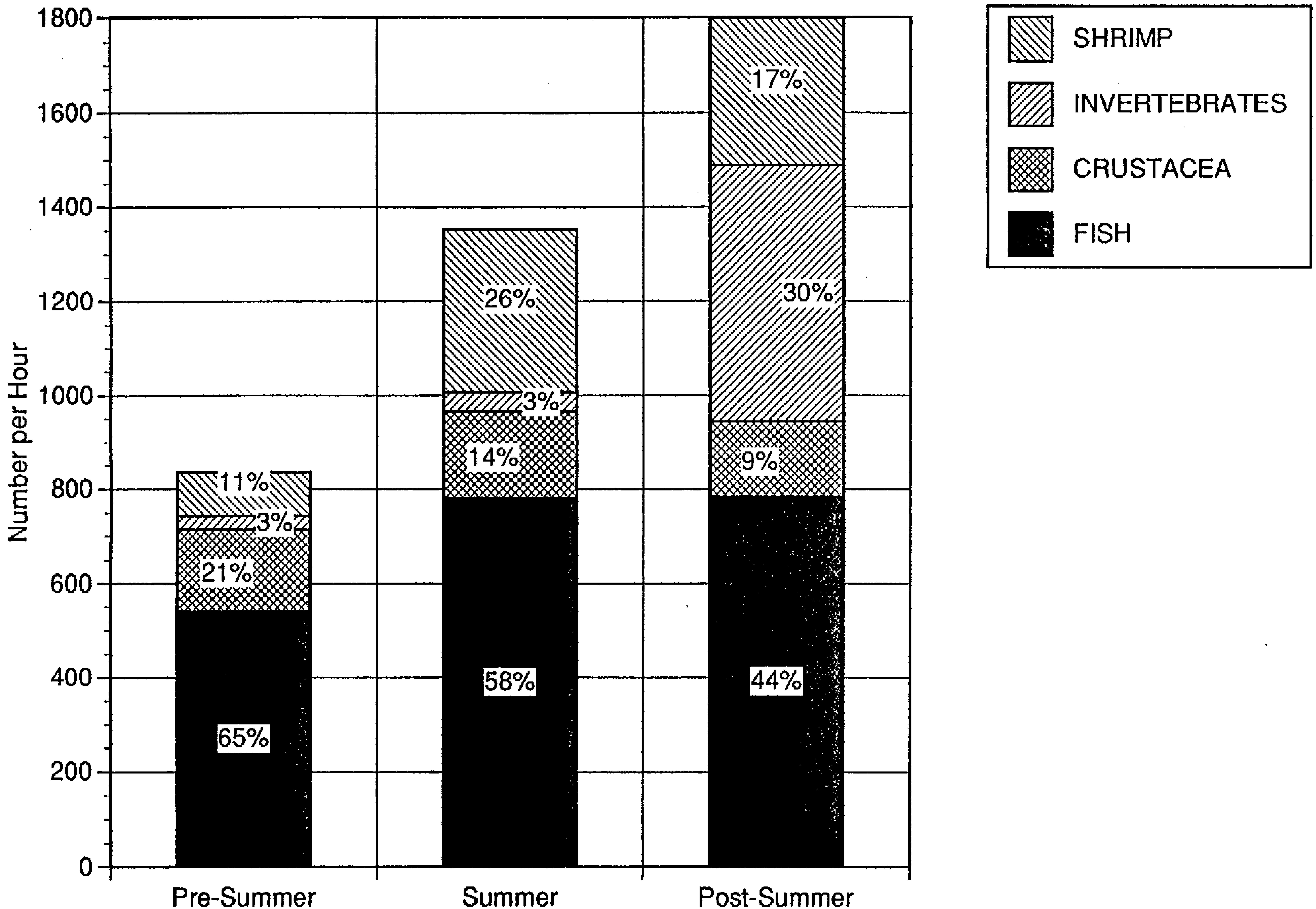
## SHRIMP CHARACTERIZATION

## CATCH (NUMBER) PER UNIT EFFORT GRAPHS
## (SPECIES GROUPS)

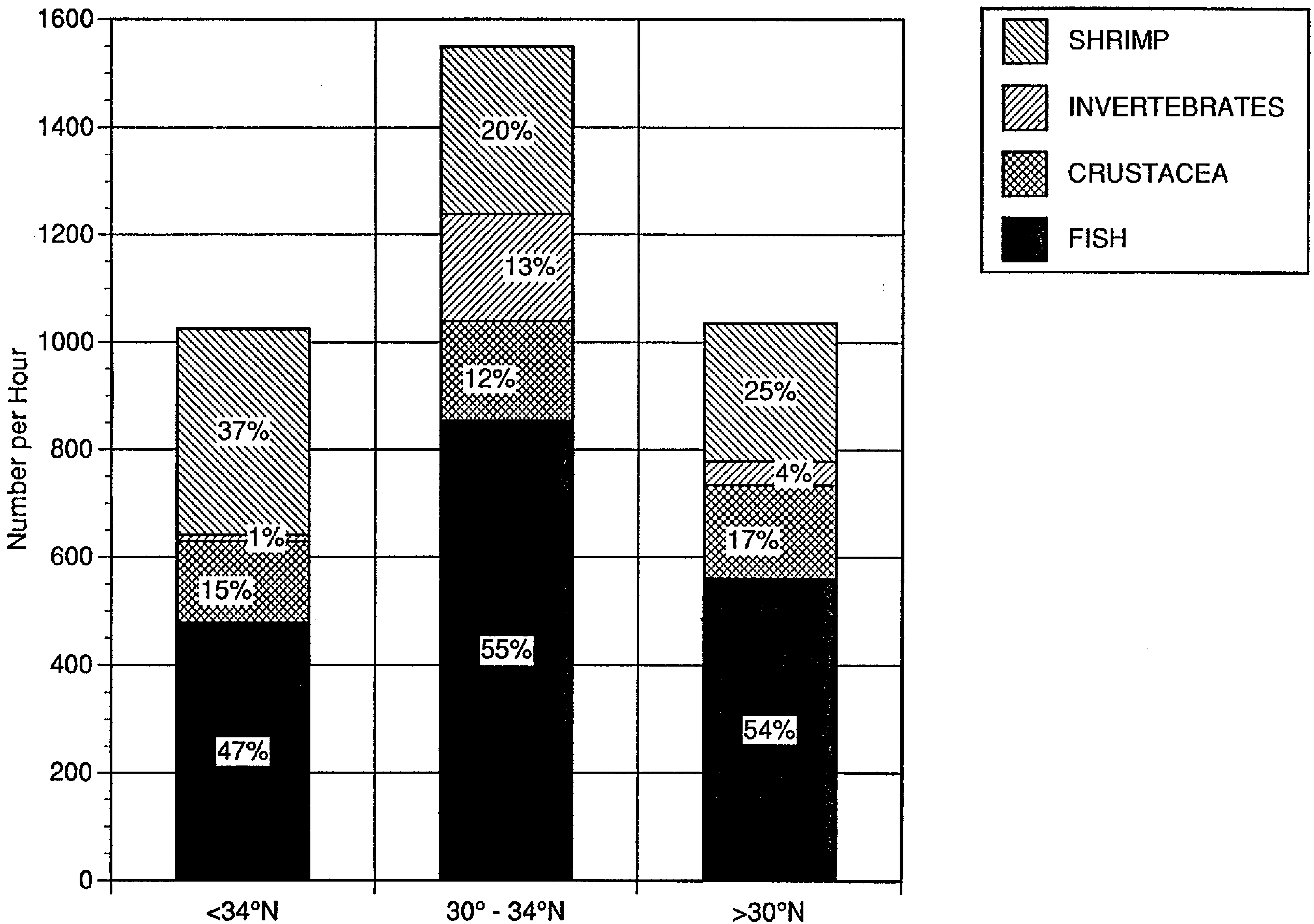
# Atlantic Catch



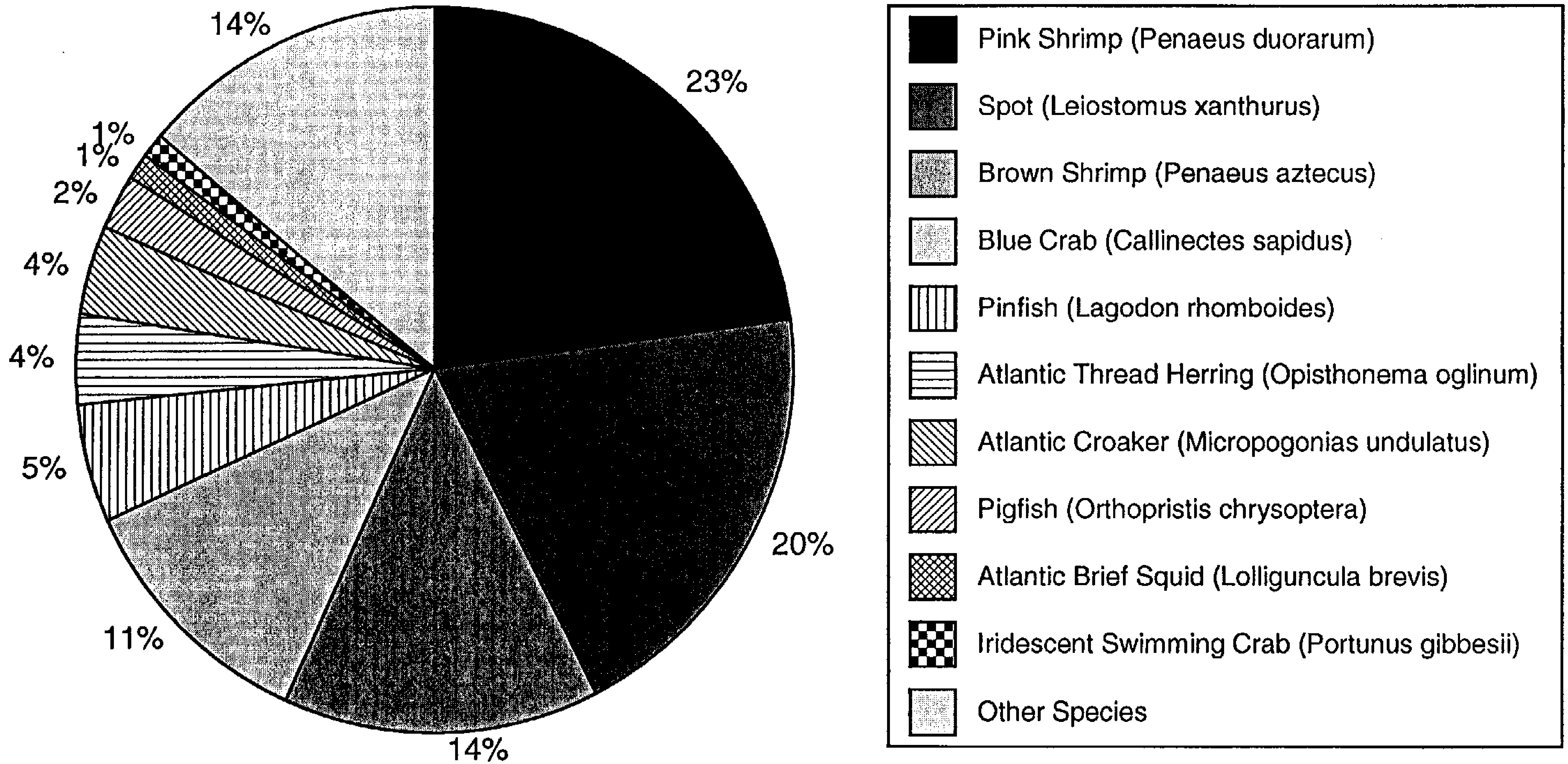
# Atlantic Catch



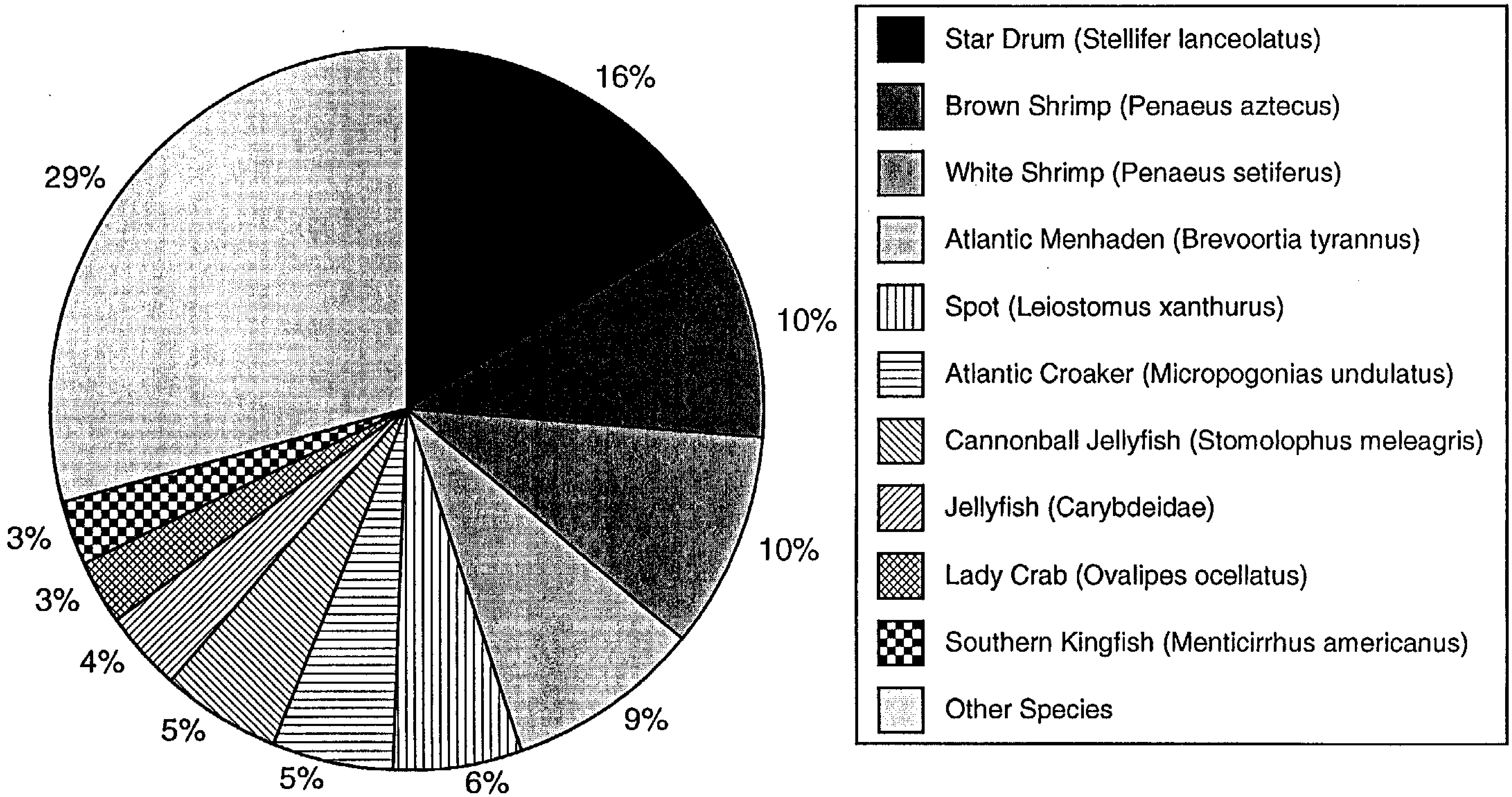
# Atlantic Catch



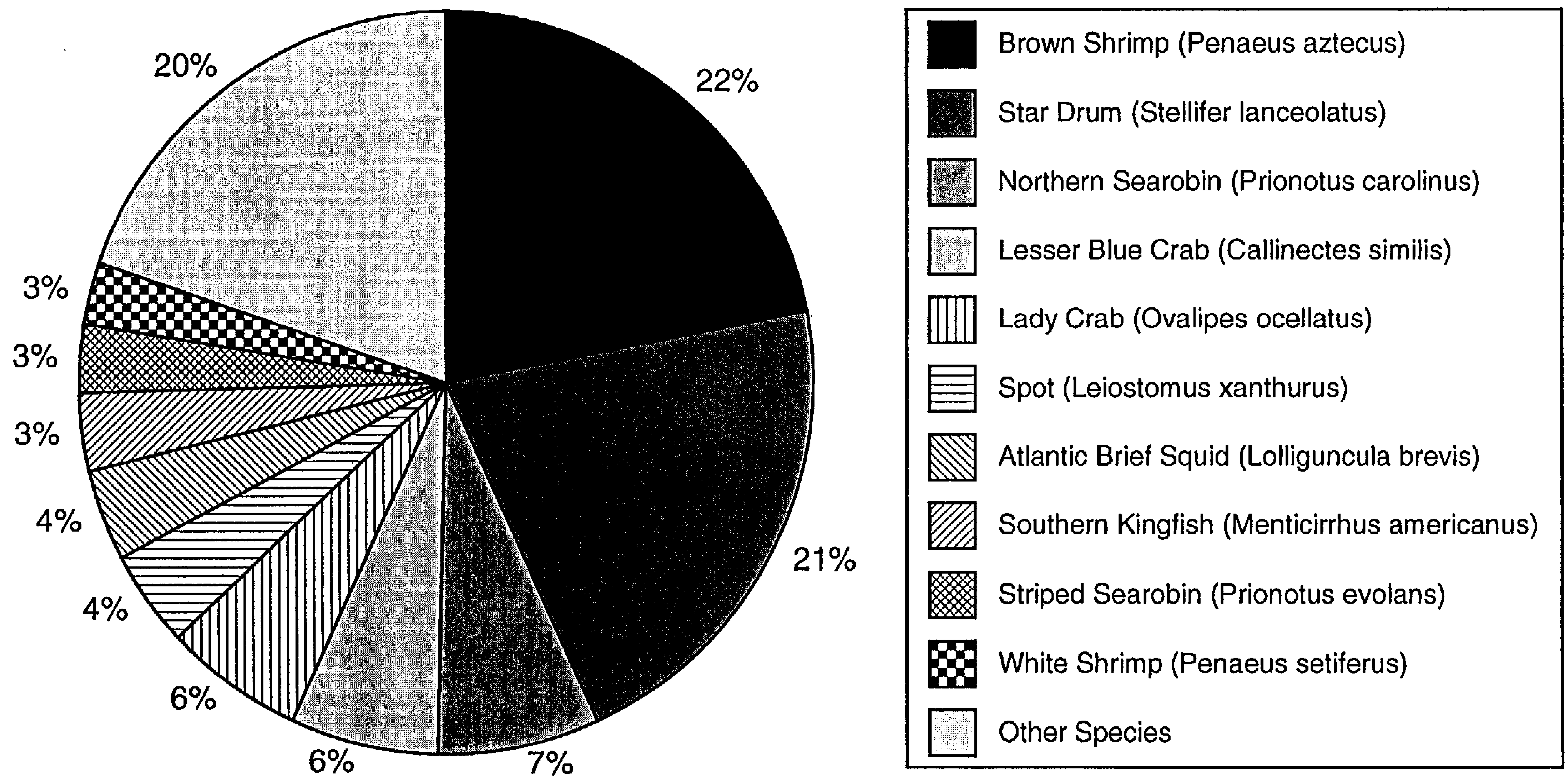
# Atlantic (>34°N) Number per Hour



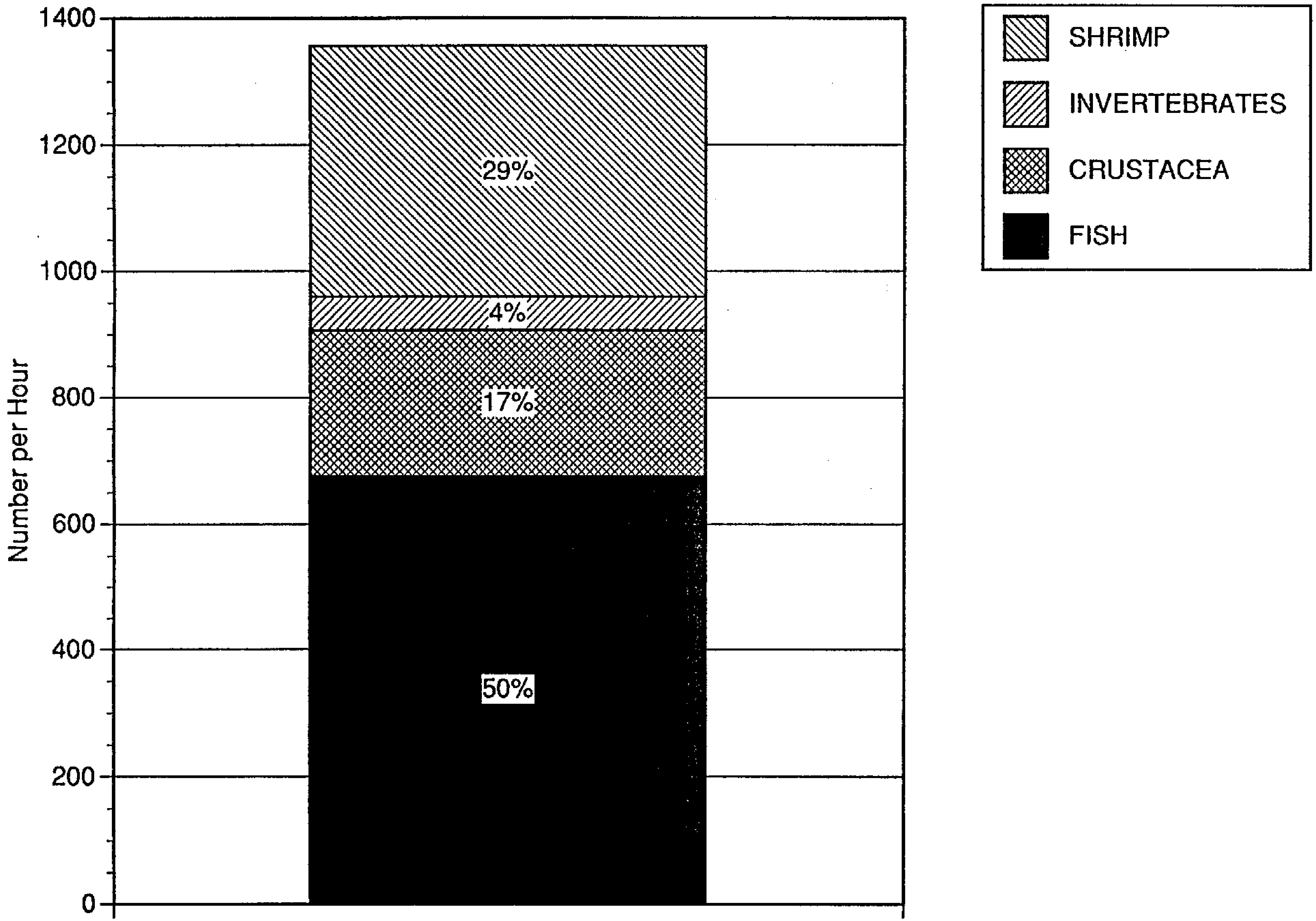
# Atlantic (30°-34°N) Number per Hour



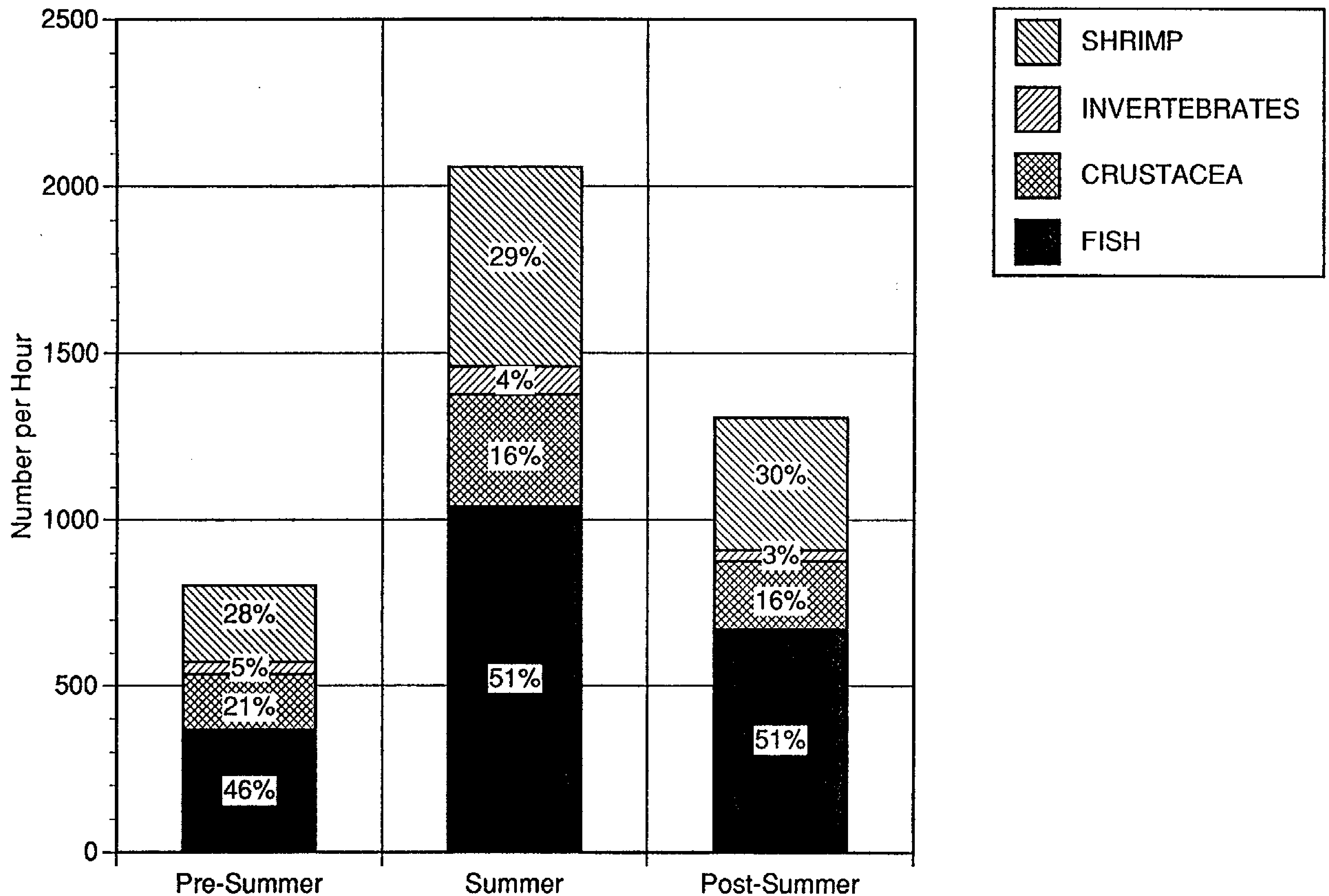
# Atlantic (<30°N) Number per Hour

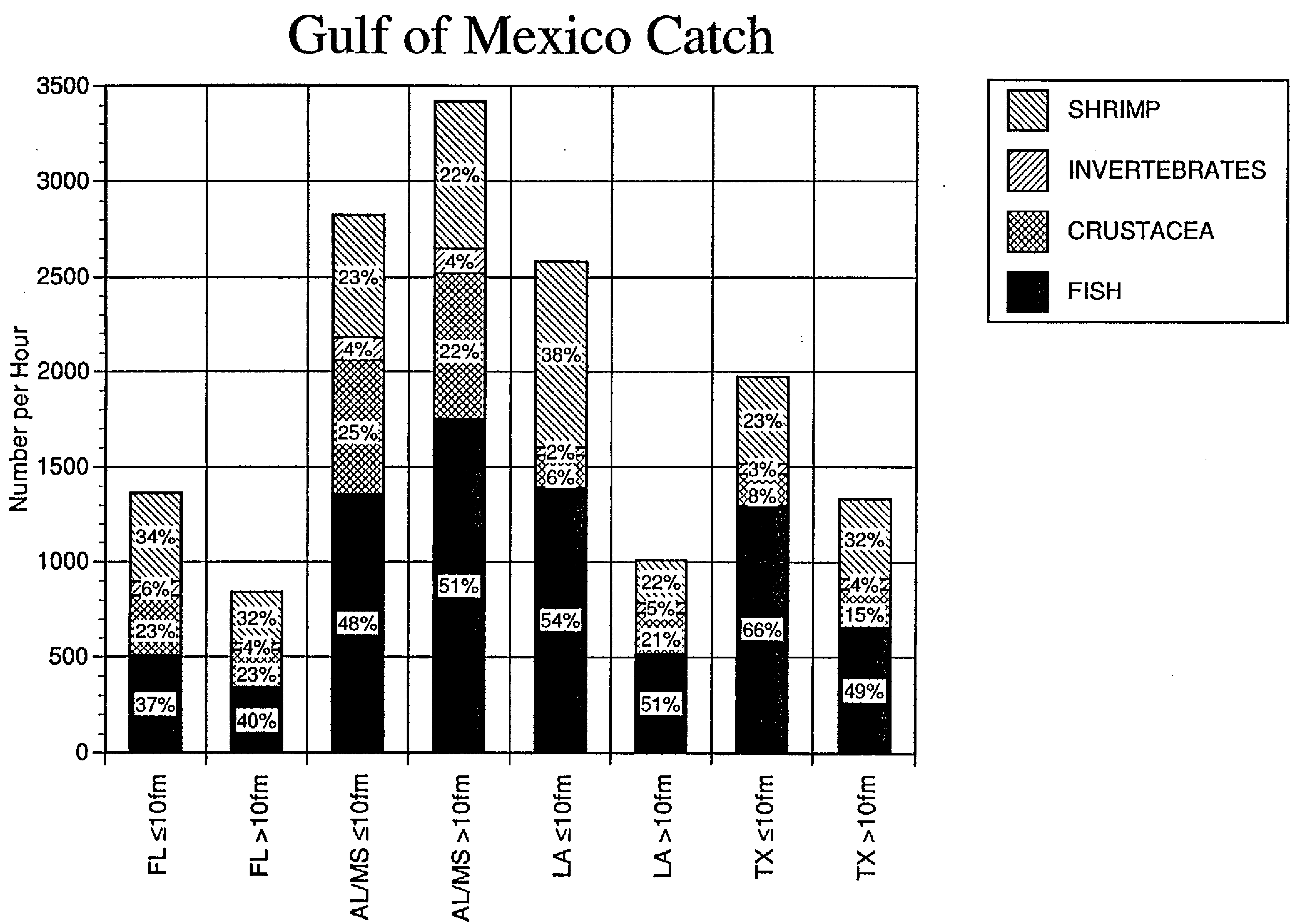


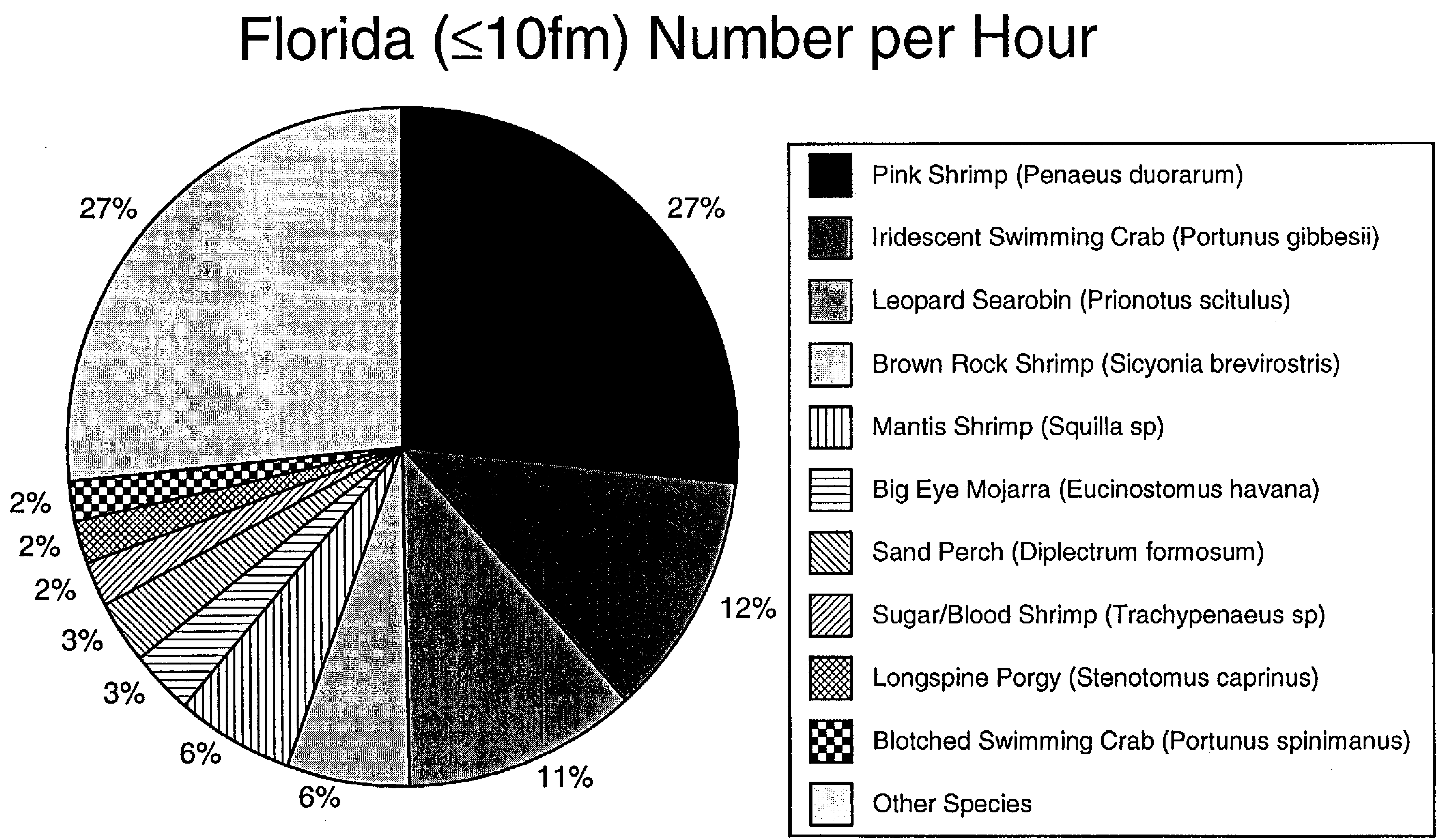
# Gulf of Mexico Catch



# Gulf of Mexico Catch

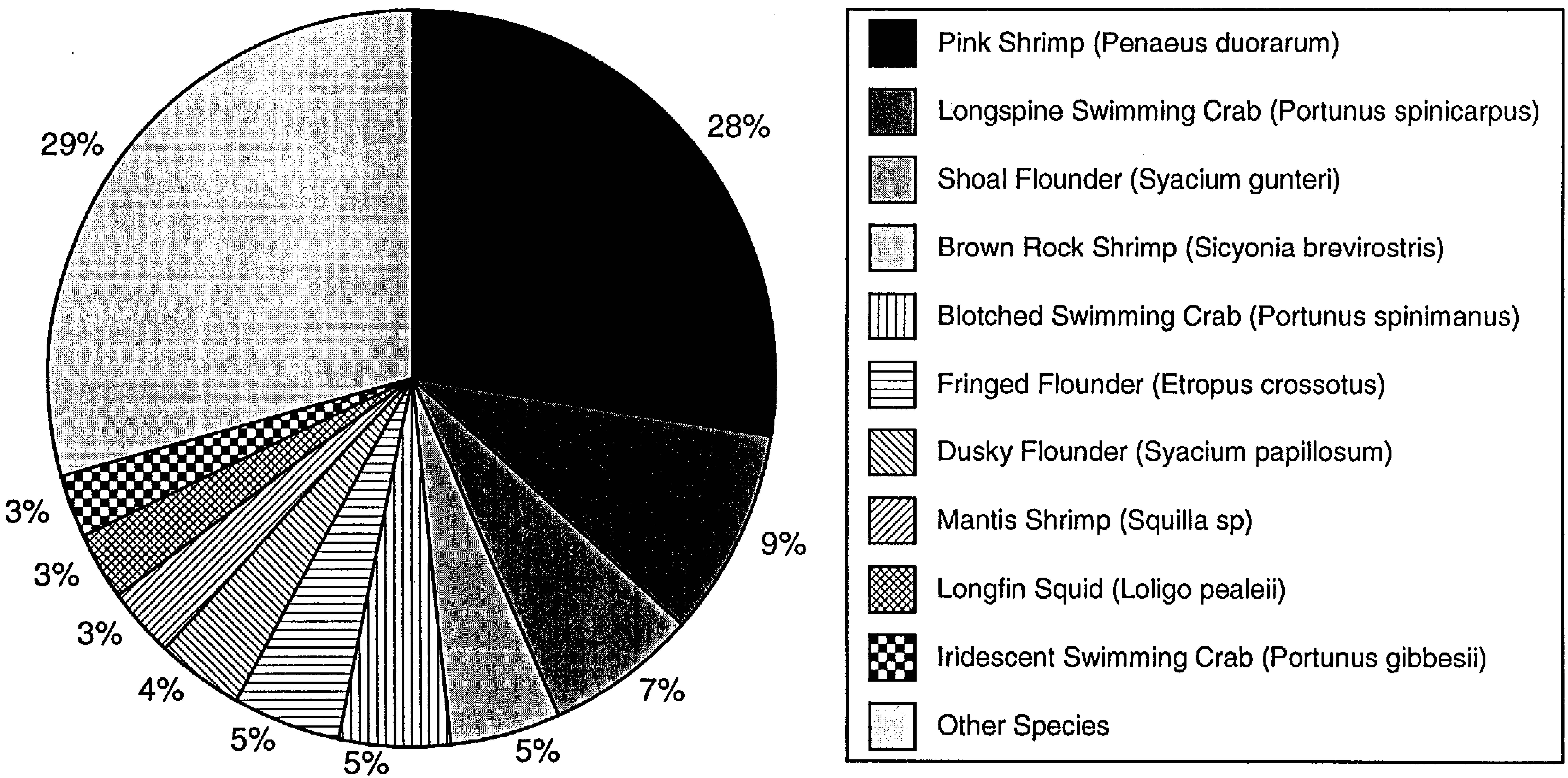



Gulf of Mexico Catch
Number per Hour
3500
3000
2500
2000
1500
1000
500
0
SHRIMP
INVERTEBRATES
CRUSTACEA
FISH
FL ≤10fm
FL >10fm
AL/MS ≤10fm
AL/MS >10fm
LA ≤10fm
LA >10fm
TX ≤10fm
TX >10fm
34%
6%
23%
37%
32%
4%
23%
40%
23%
4%
25%
48%
22%
4%
22%
51%
38%
2%
6%
54%
22%
5%
21%
51%
23%
3%
8%
66%
32%
4%
15%
49%

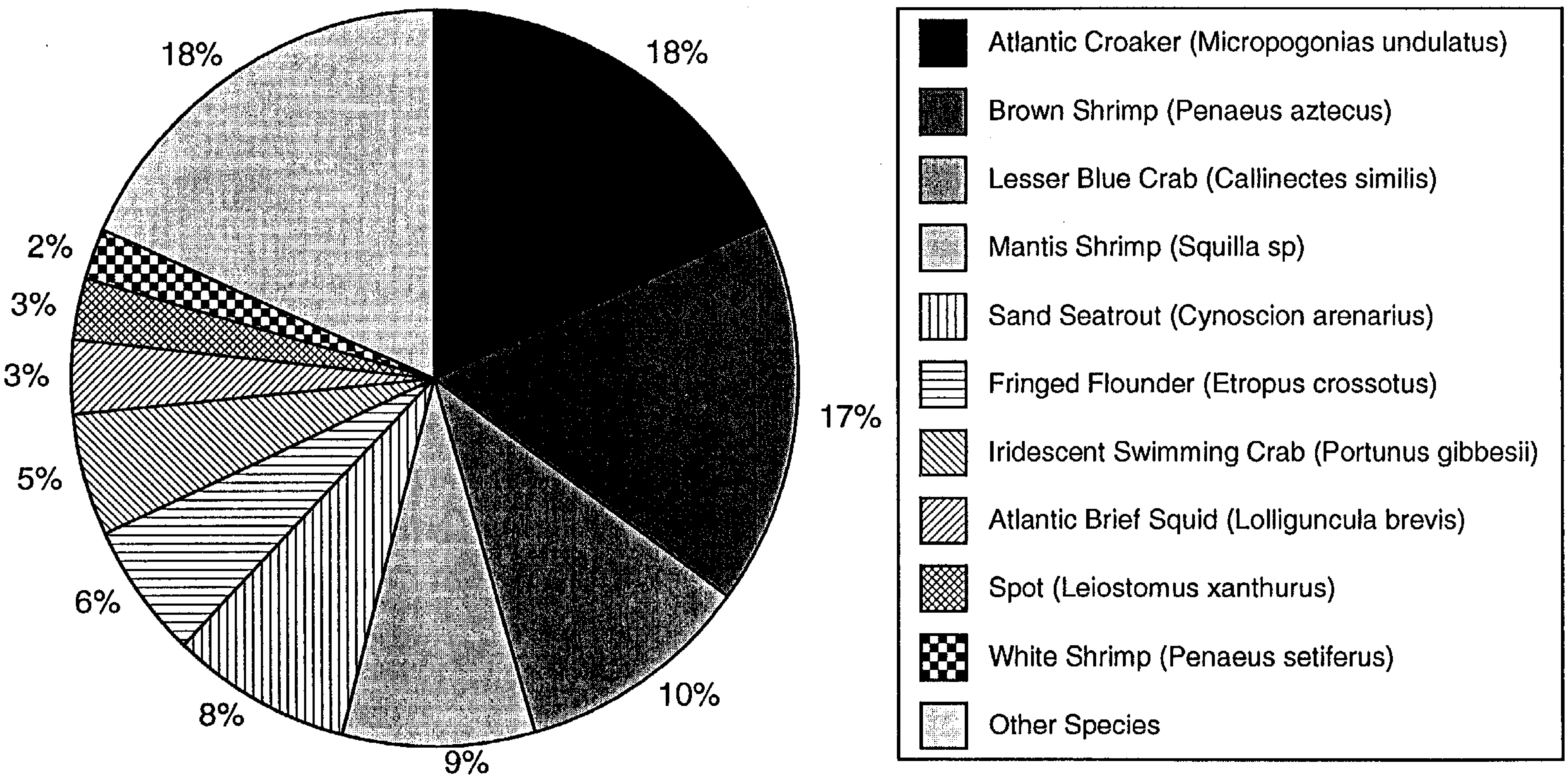


Florida (≤10fm) Number per Hour
27%
27%
12%
11%
6%
6%
3%
3%
2%
2%
2%
Pink Shrimp (Penaeus duorarum)
Iridescent Swimming Crab (Portunus gibbesii)
Leopard Searobin (Prionotus scitulus)
Brown Rock Shrimp (Sicyonia brevirostris)
Mantis Shrimp (Squilla sp)
Big Eye Mojarra (Eucinostomus havana)
Sand Perch (Diplectrum formosum)
Sugar/Blood Shrimp (Trachypenaeus sp)
Longspine Porgy (Stenotomus caprinus)
Blotched Swimming Crab (Portunus spinimanus)
Other Species

# Florida (>10fm) Number per Hour

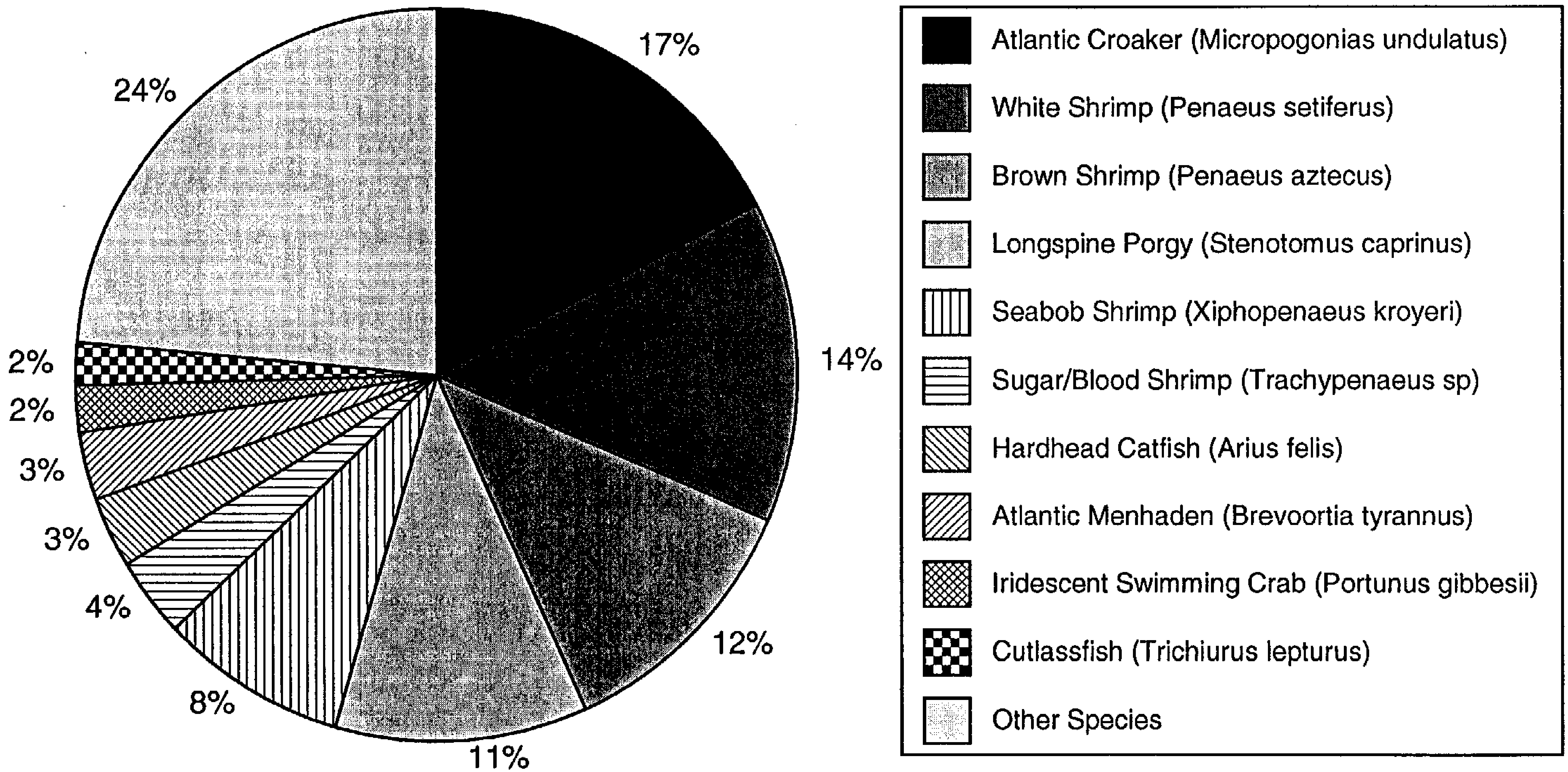


# AL/MS (≤10fm) Number per Hour



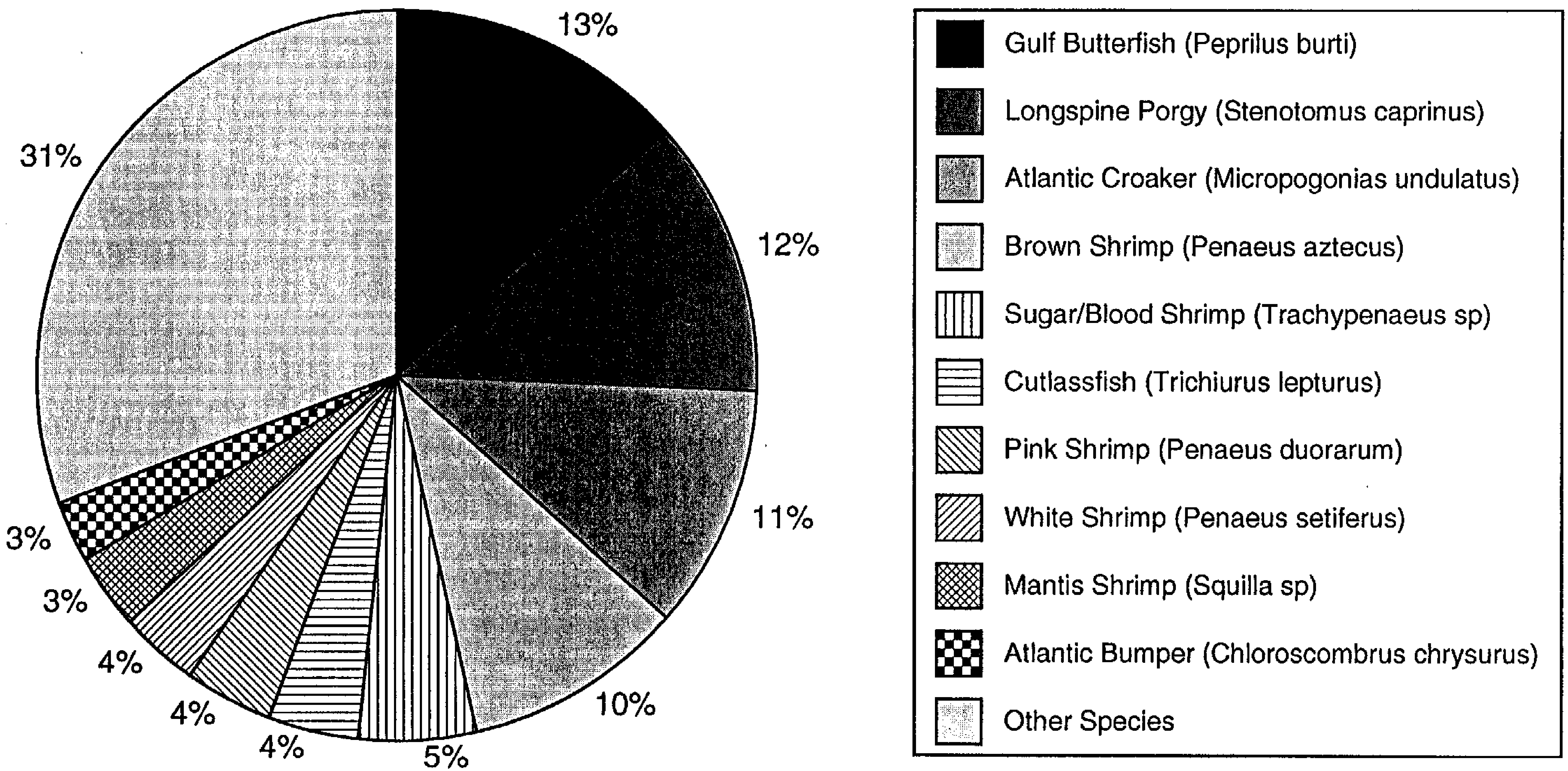
# AL/MS (>10fm) Number per Hour

# Louisiana (≤10fm) Number per Hour

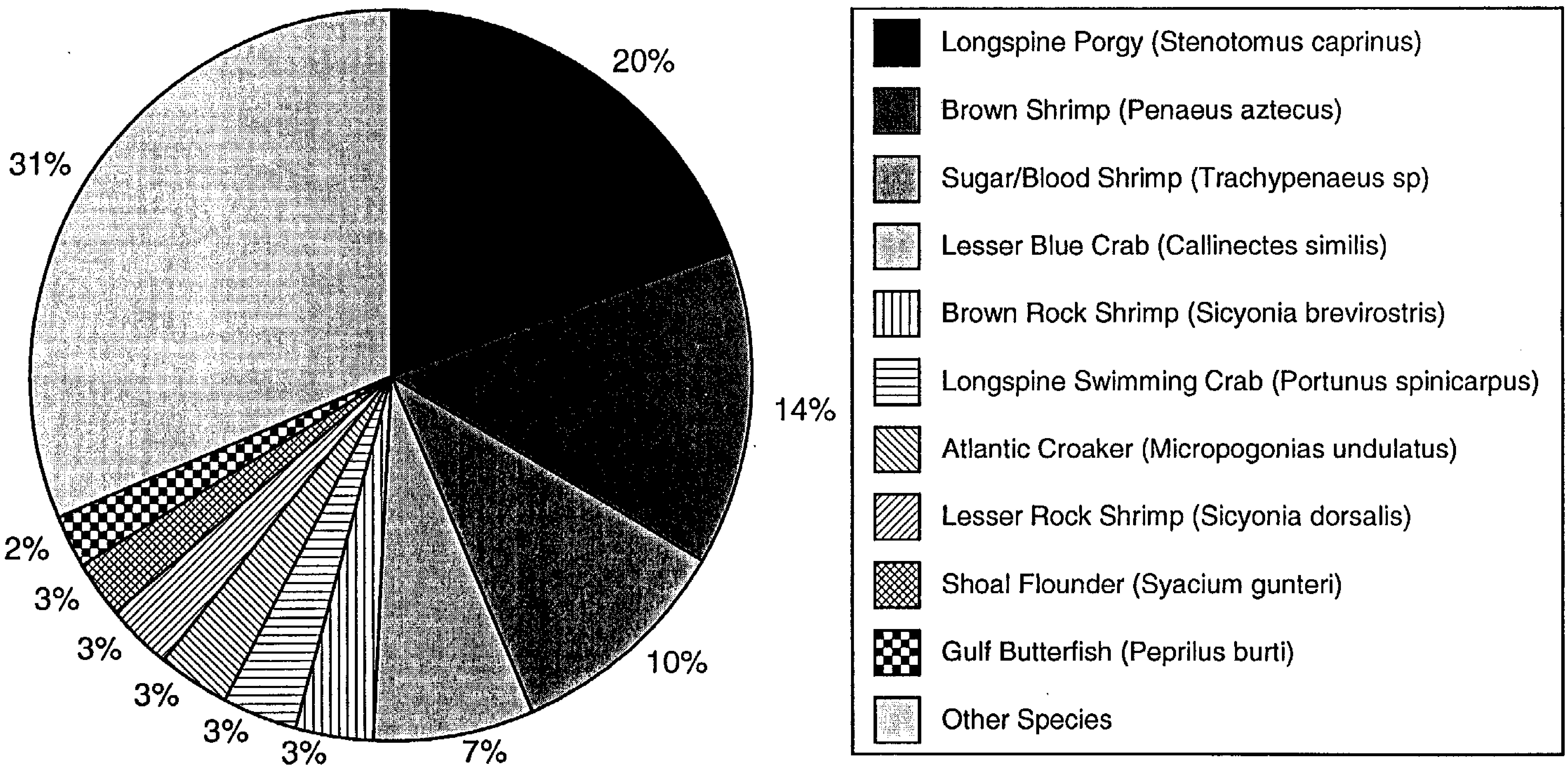


# Louisiana (>10fm) Number per Hour

# Texas (≤10fm) Number per Hour



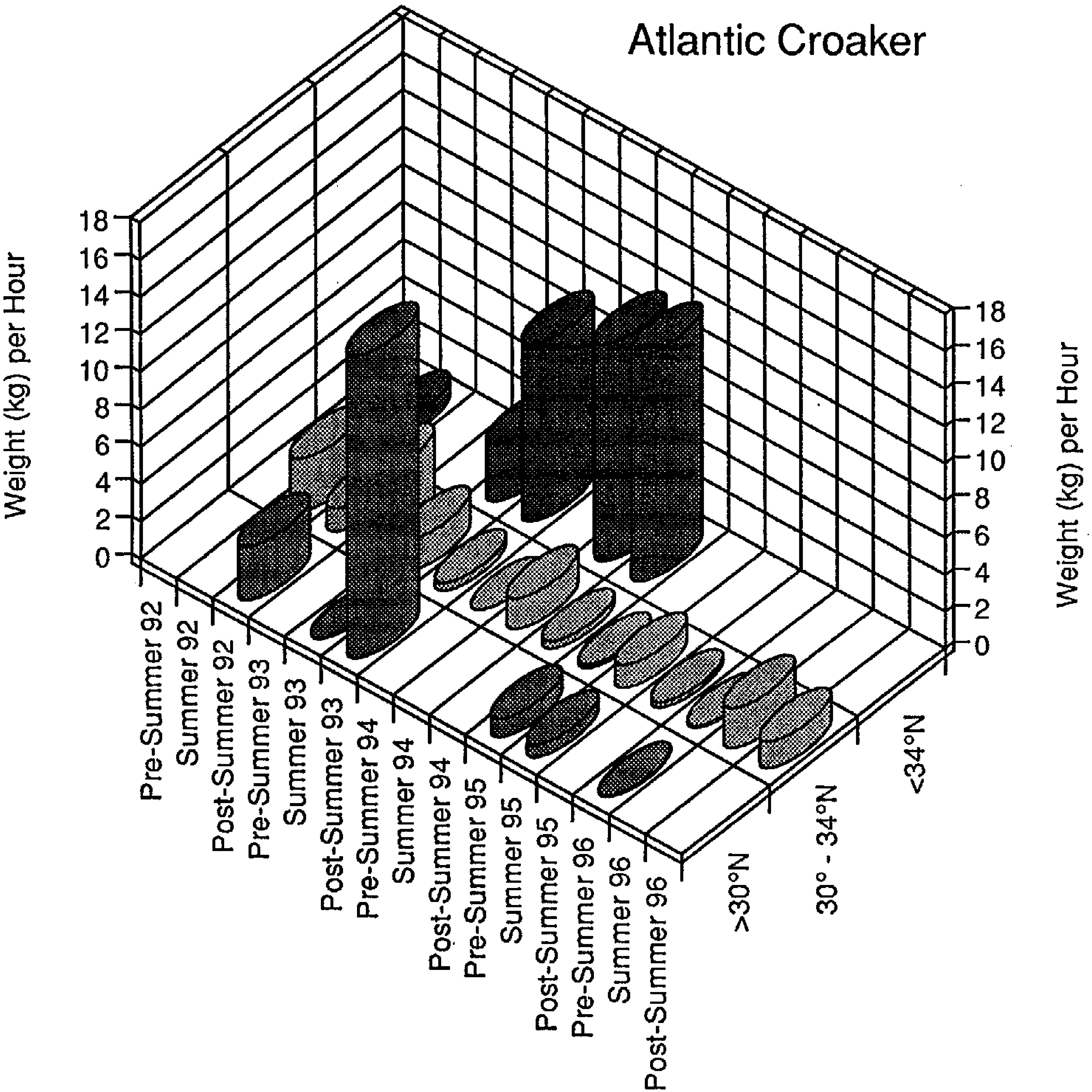
# Texas (>10fm) Number per Hour



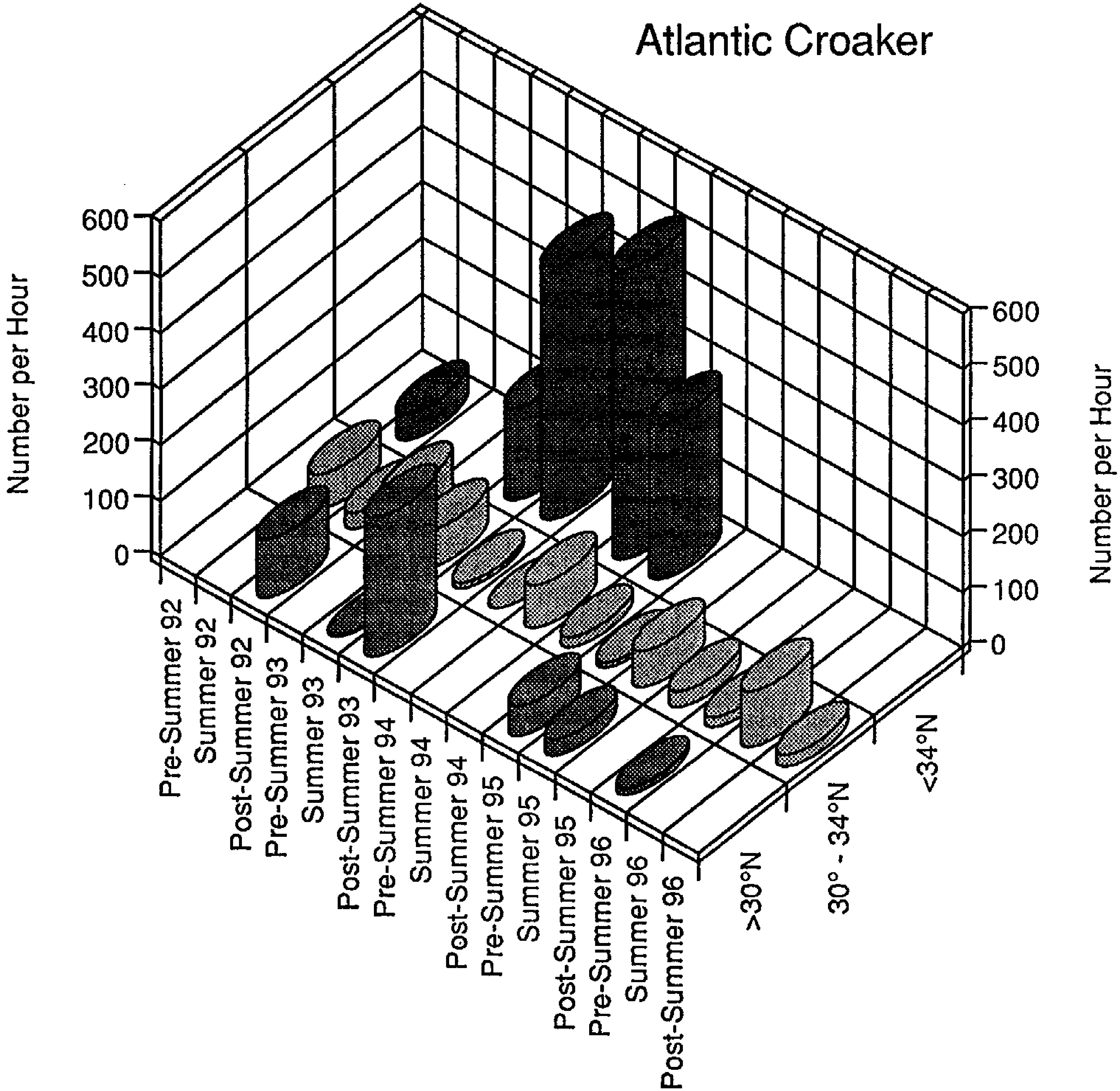
# SECTION 2: APPENDIX III

## SHRIMP CHARACTERIZATION

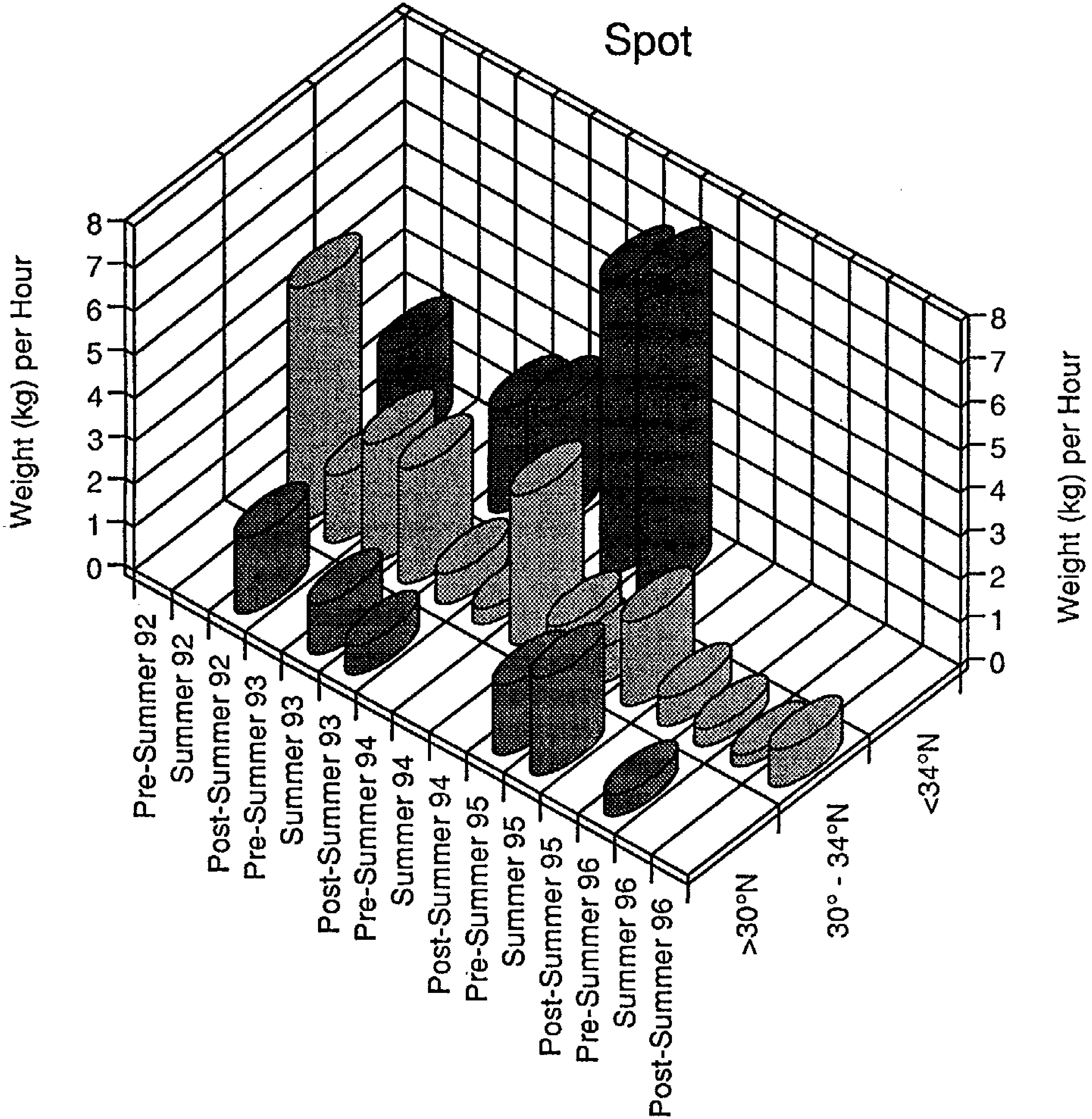
## CATCH (WEIGHT AND NUMBER) PER UNIT EFFORT GRAPHS (SELECTED SPECIES)



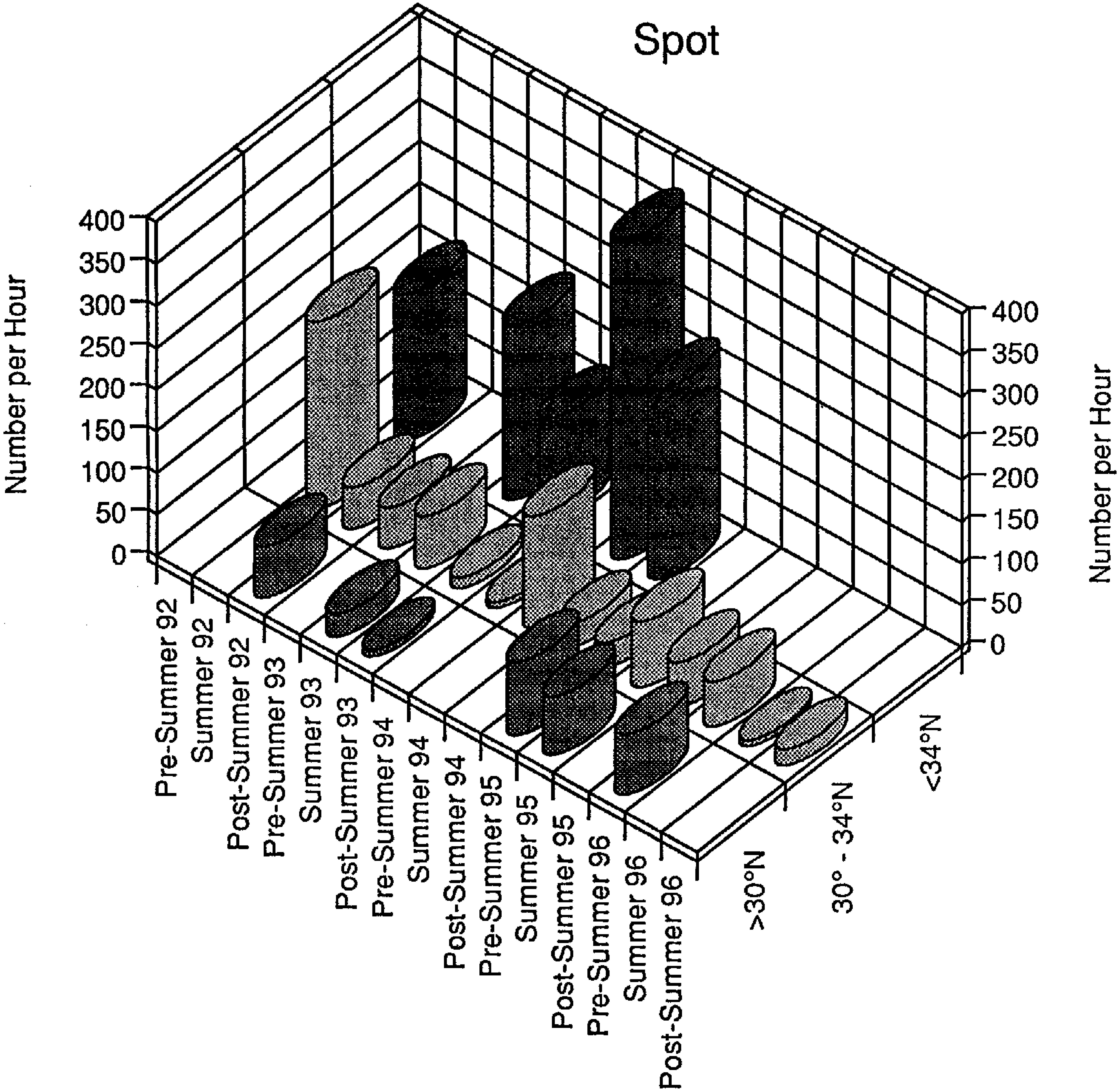
Atlantic Croaker
Weight (kg) per Hour
0
2
4
6
8
10
12
14
16
18
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N



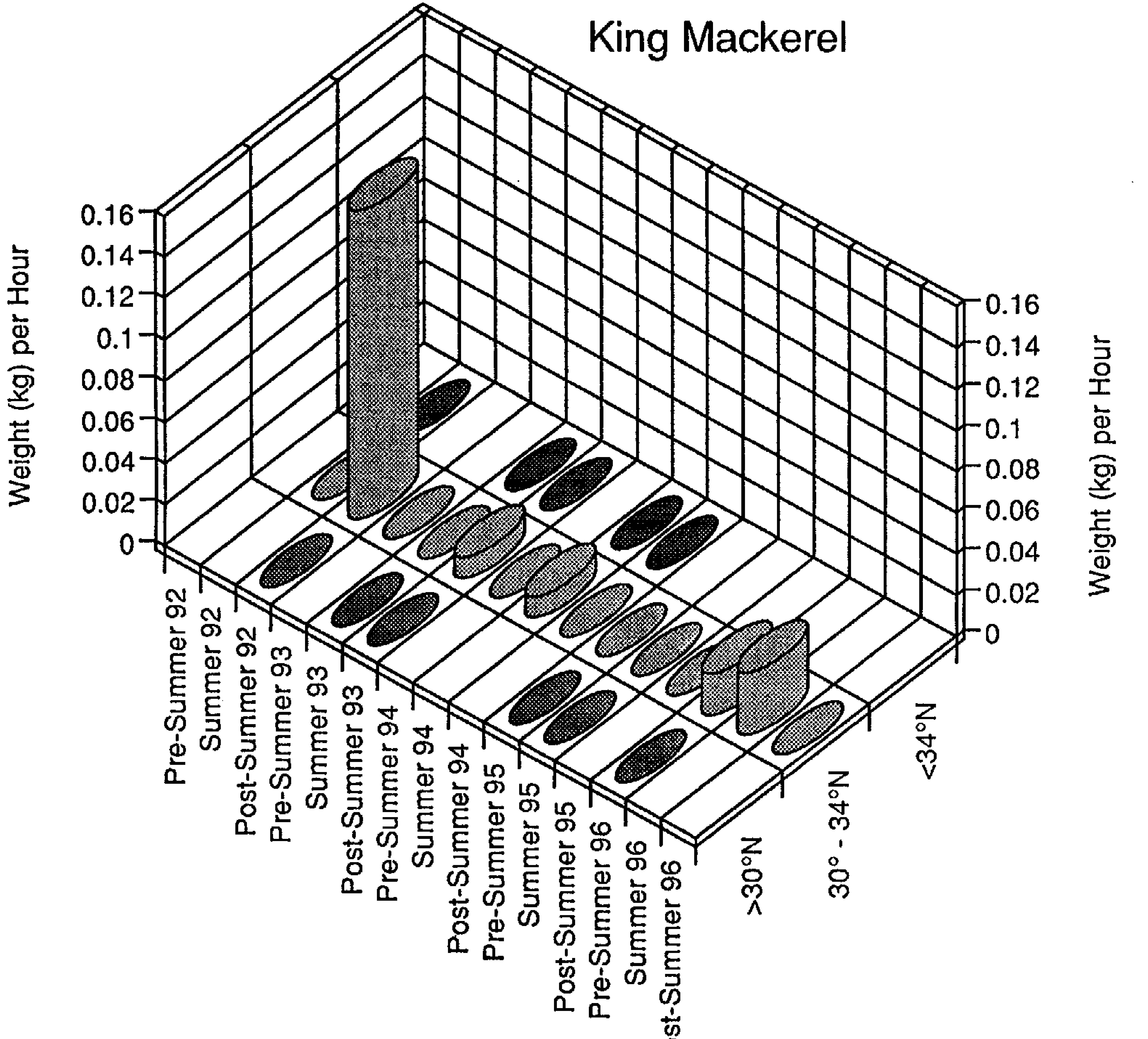
Atlantic Croaker
Number per Hour
600
500
400
300
200
100
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N



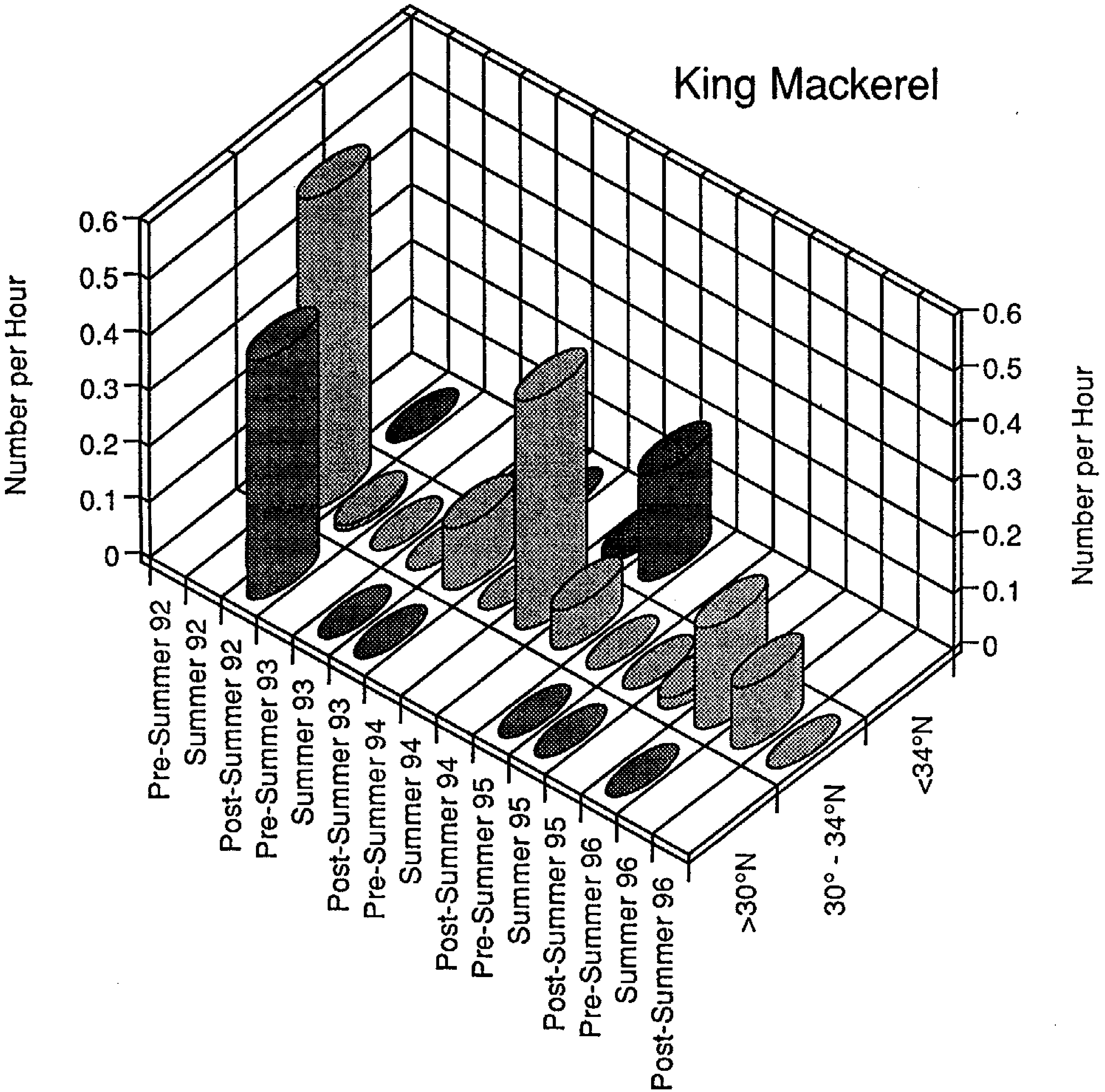
Spot
Weight (kg) per Hour
0
1
2
3
4
5
6
7
8
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N



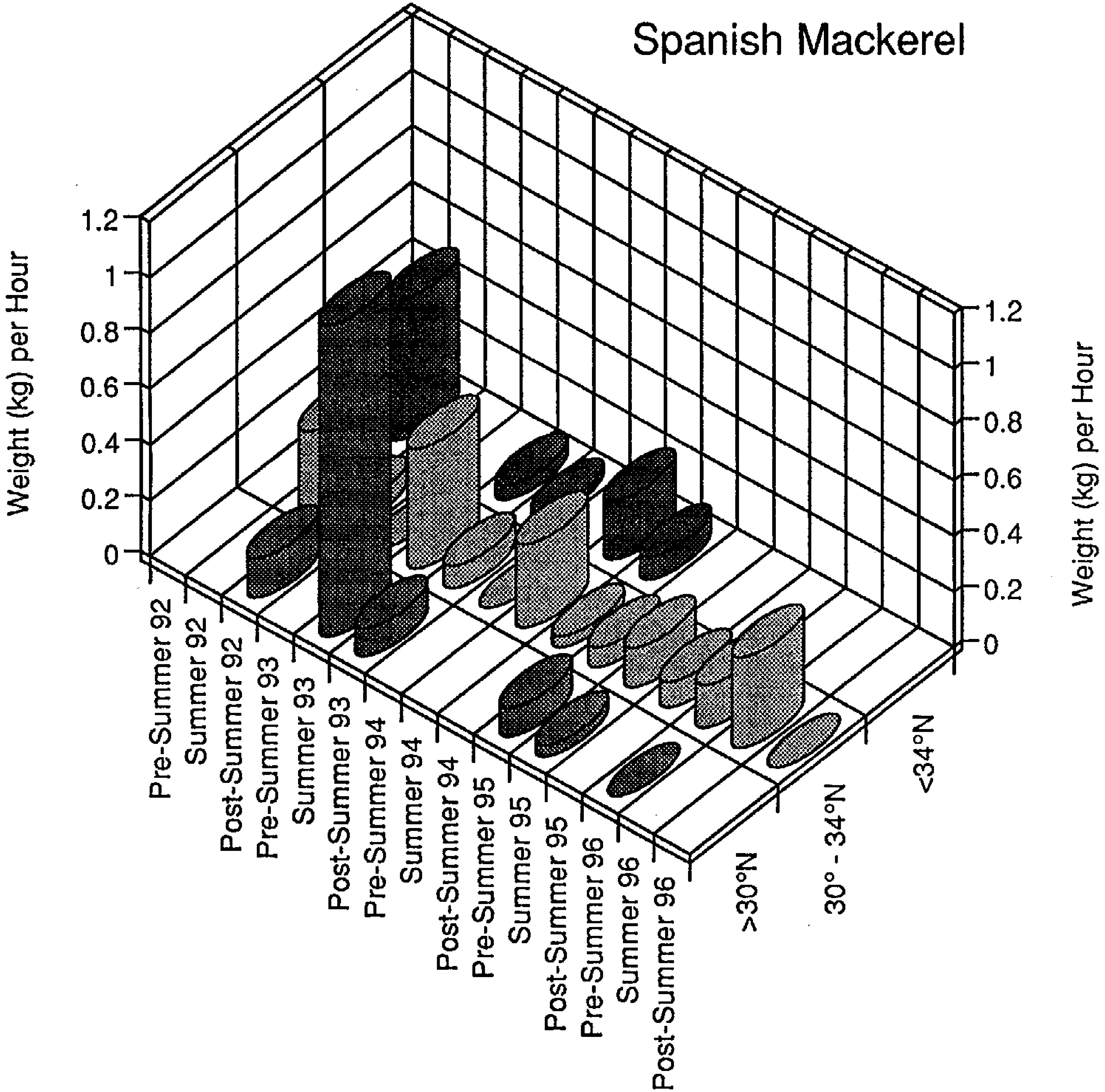
Spot
Number per Hour
400
350
300
250
200
150
100
50
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N



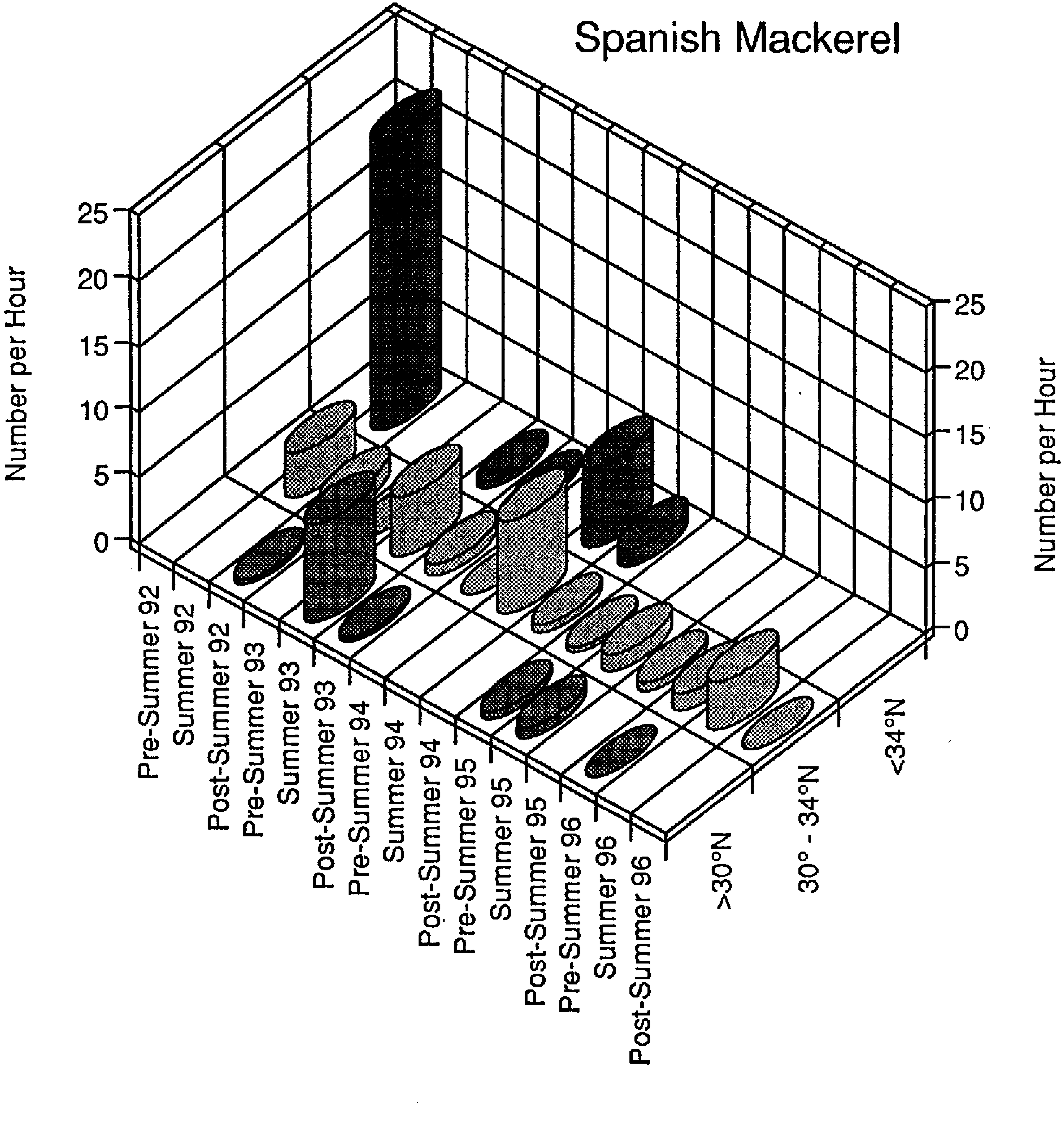
King Mackerel
Weight (kg) per Hour
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N

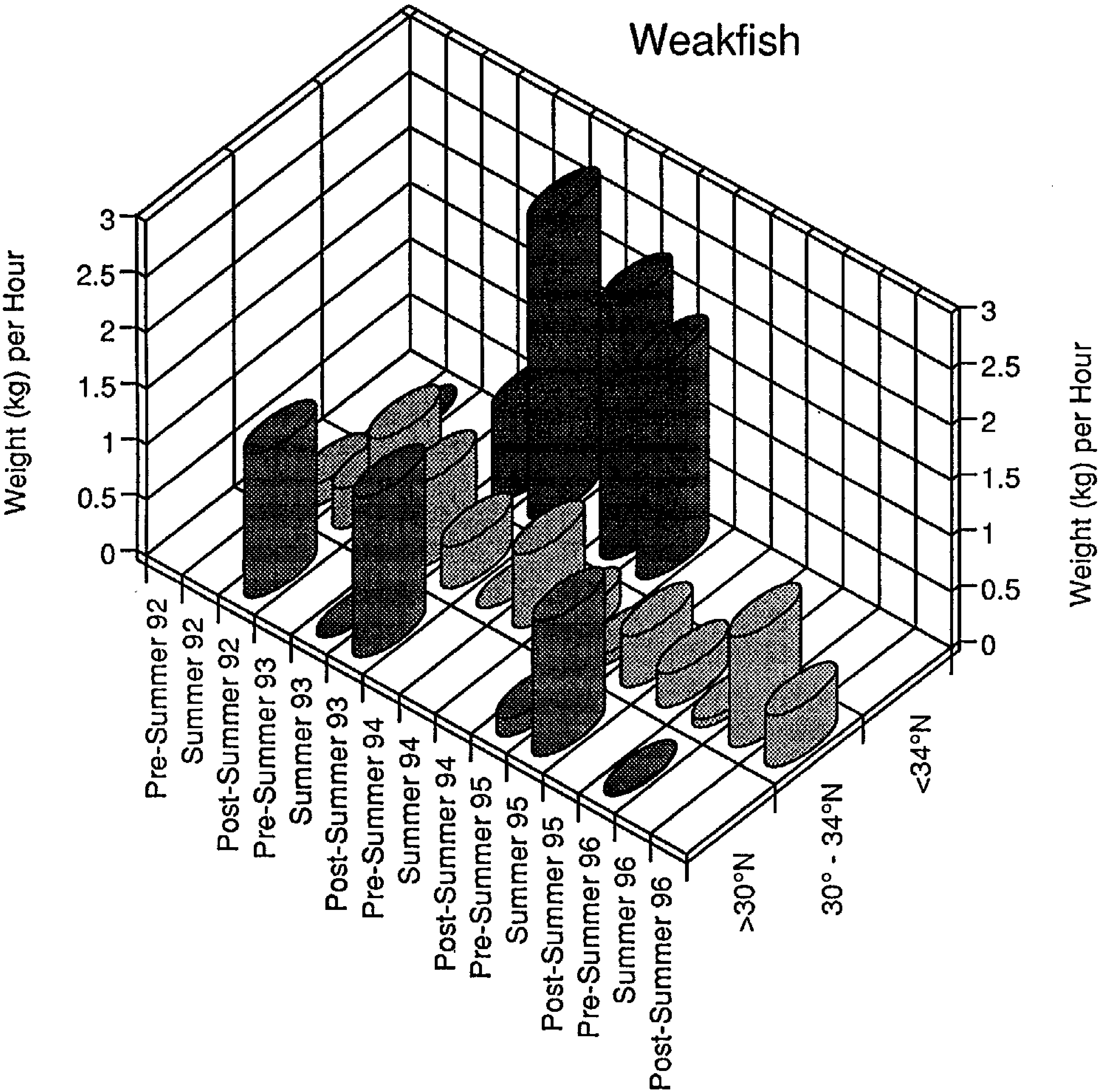


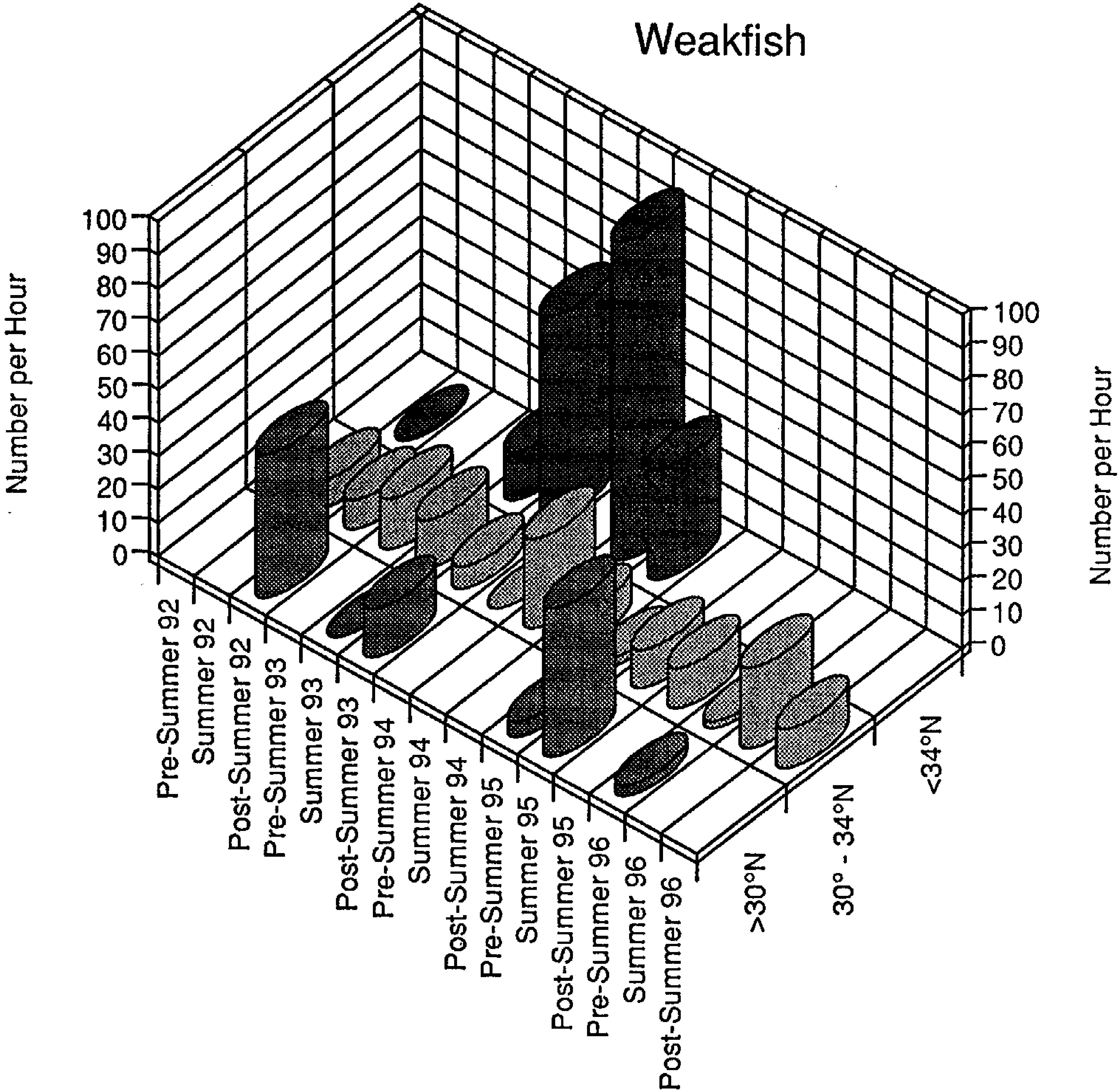
King Mackerel
Number per Hour
0.6
0.5
0.4
0.3
0.2
0.1
0
Number per Hour
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N



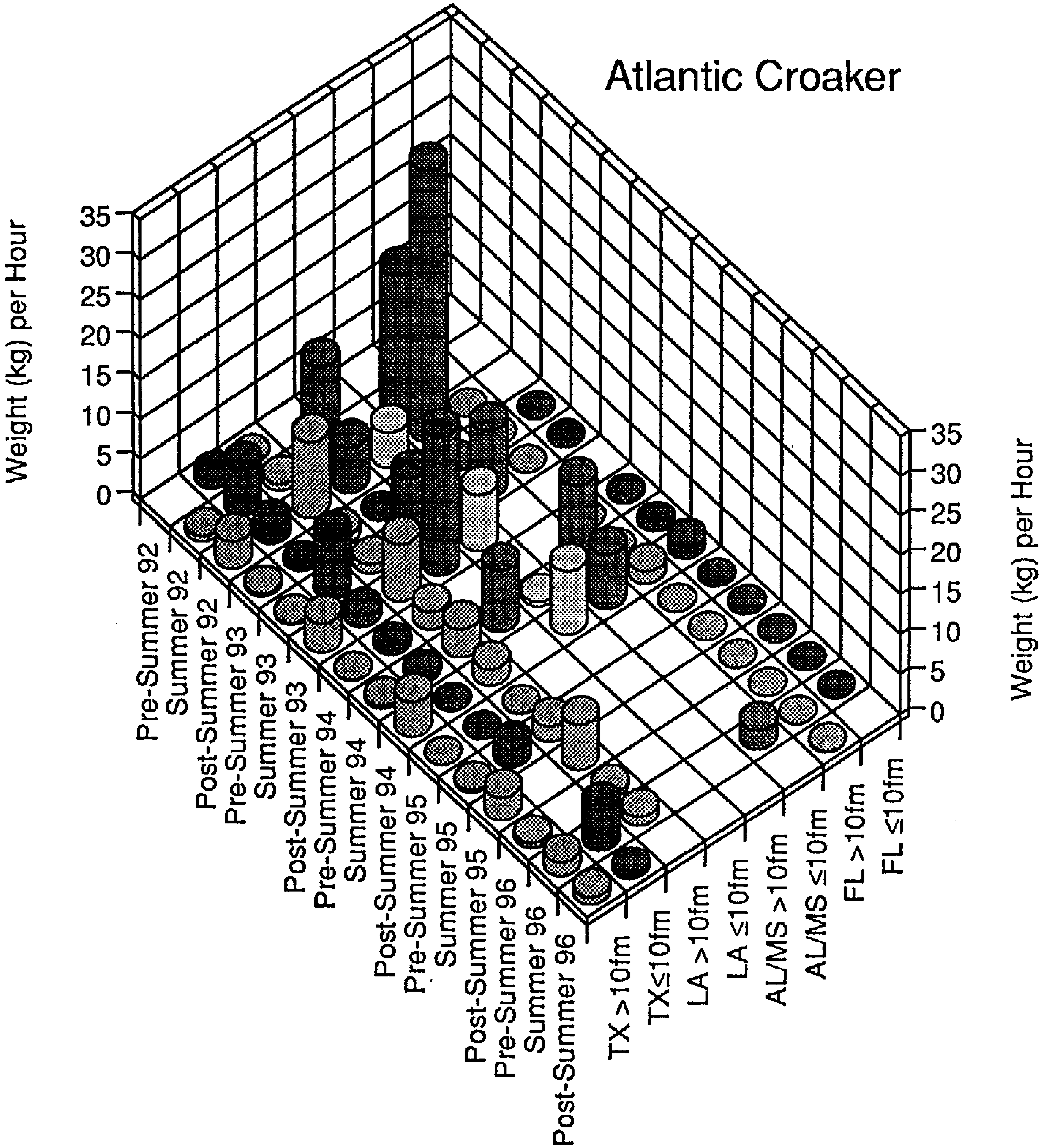
Spanish Mackerel
Weight (kg) per Hour
1.2
1
0.8
0.6
0.4
0.2
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N


Spanish Mackerel
Number per Hour
0
5
10
15
20
25
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N

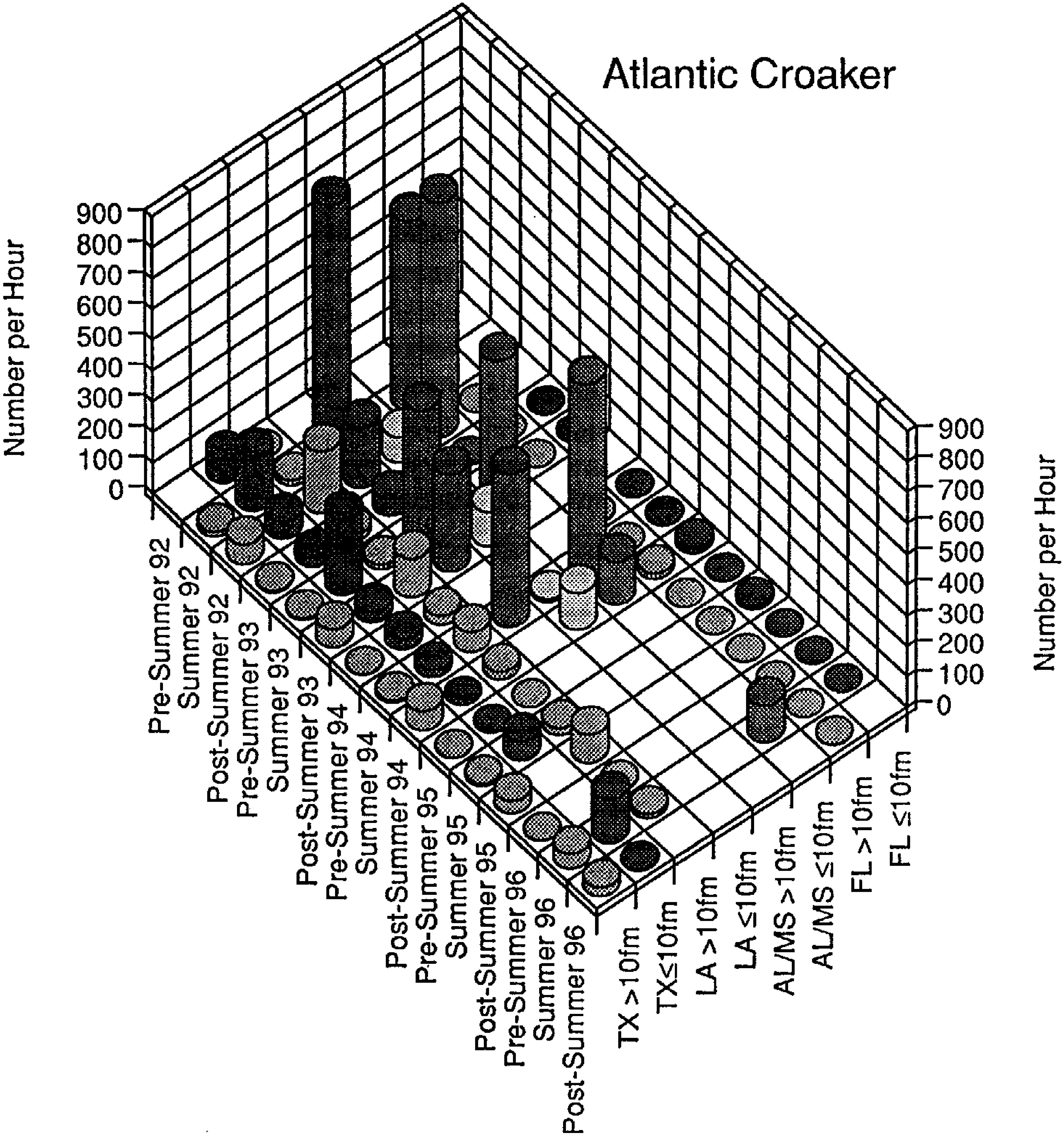

Weakfish
Weight (kg) per Hour
3
2.5
2
1.5
1
0.5
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N

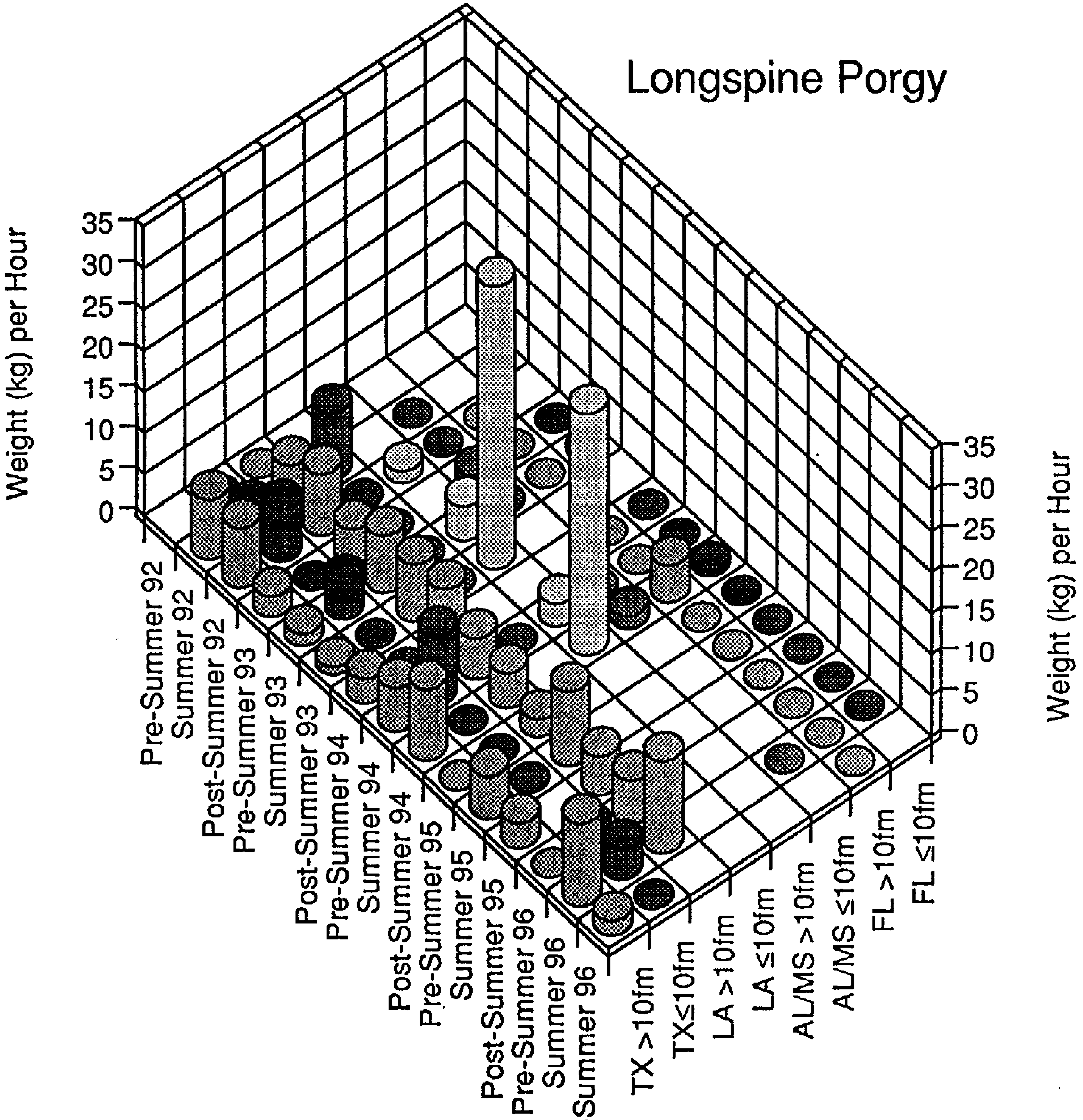


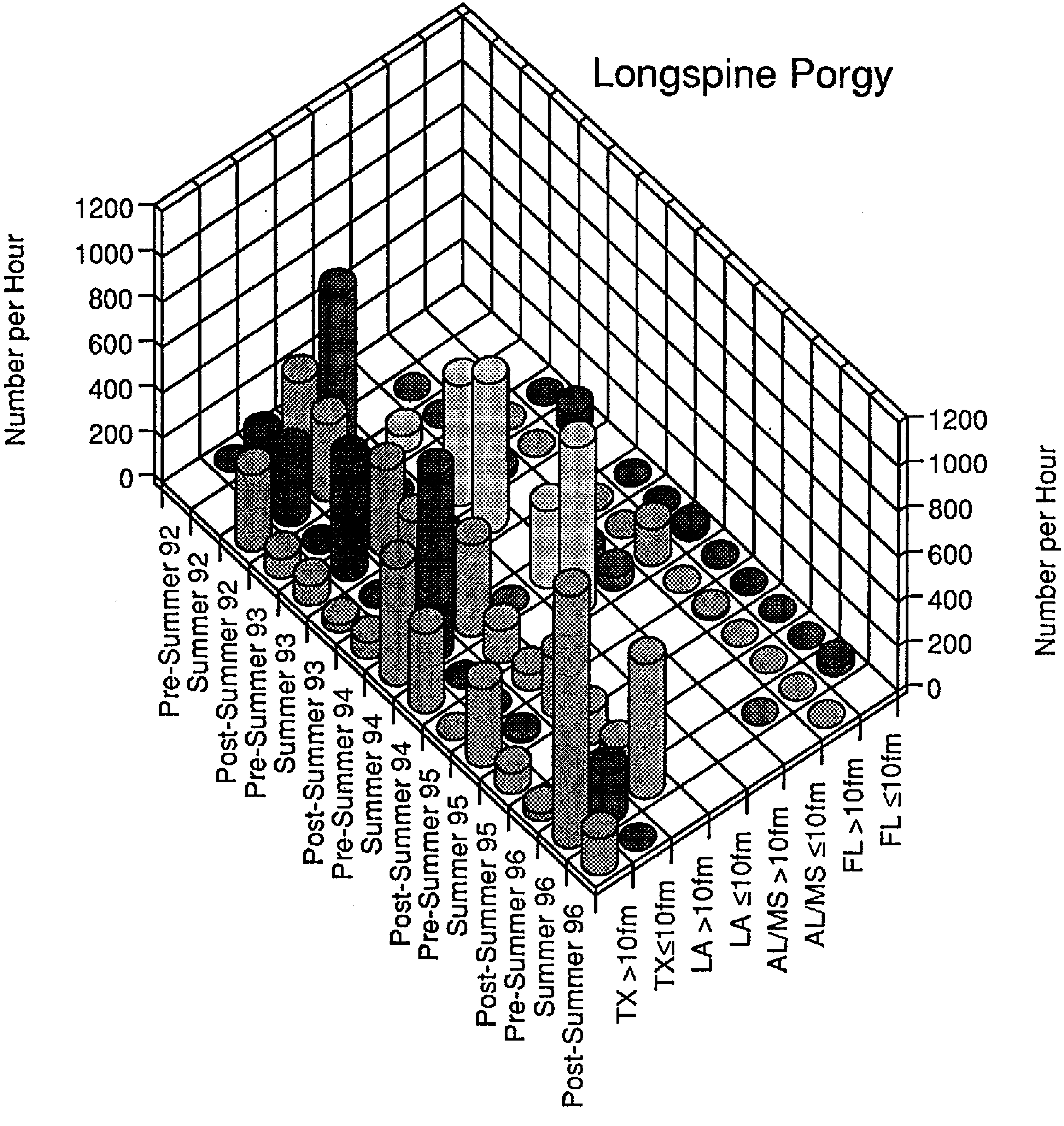
Weakfish
Number per Hour
100
90
80
70
60
50
40
30
20
10
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
>30°N
30° - 34°N
<34°N



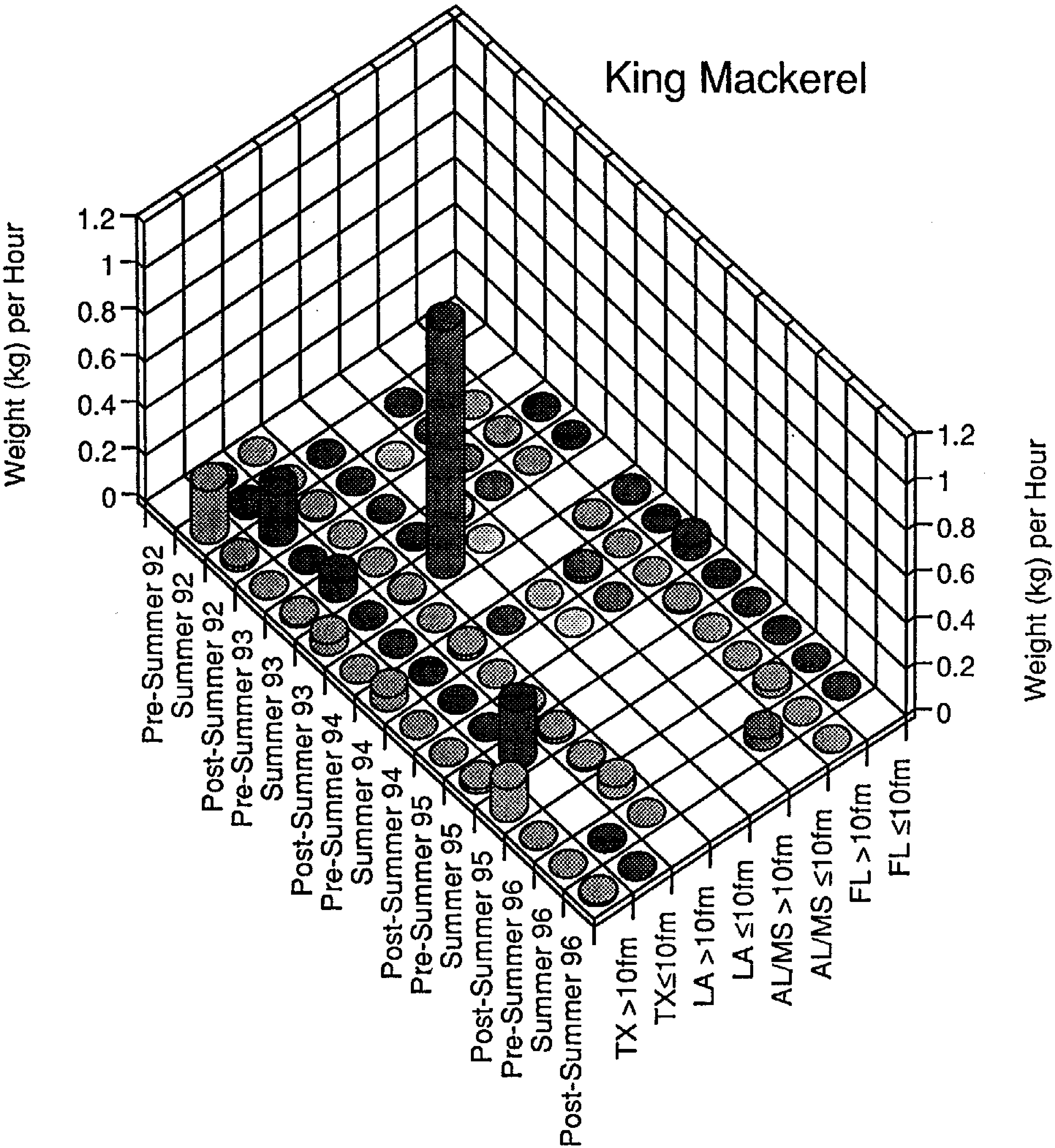
Atlantic Croaker
Weight (kg) per Hour
0
5
10
15
20
25
30
35
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm

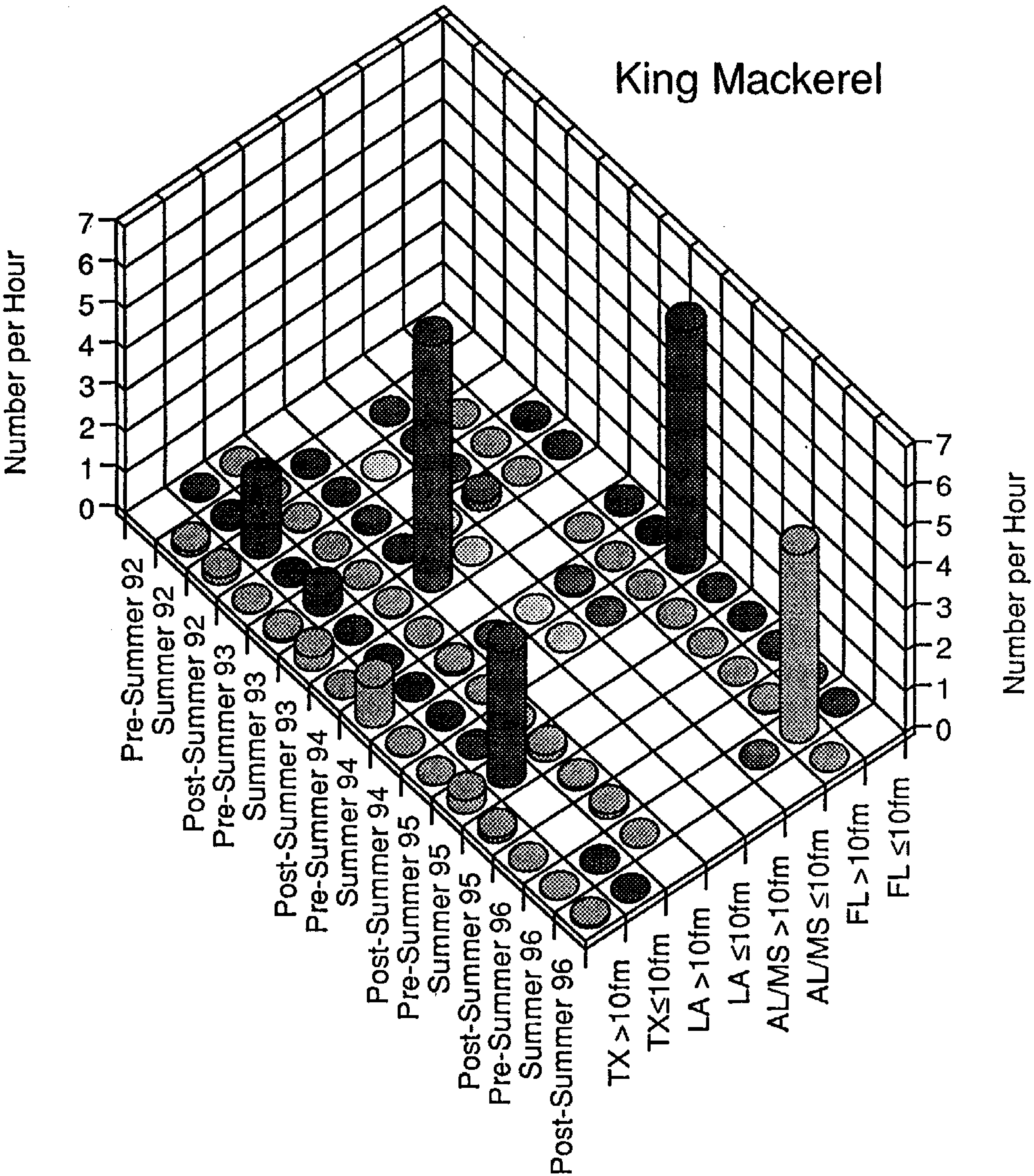

Atlantic Croaker
Number per Hour
900
800
700
600
500
400
300
200
100
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm


Longspine Porgy
Weight (kg) per Hour
35
30
25
20
15
10
5
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm

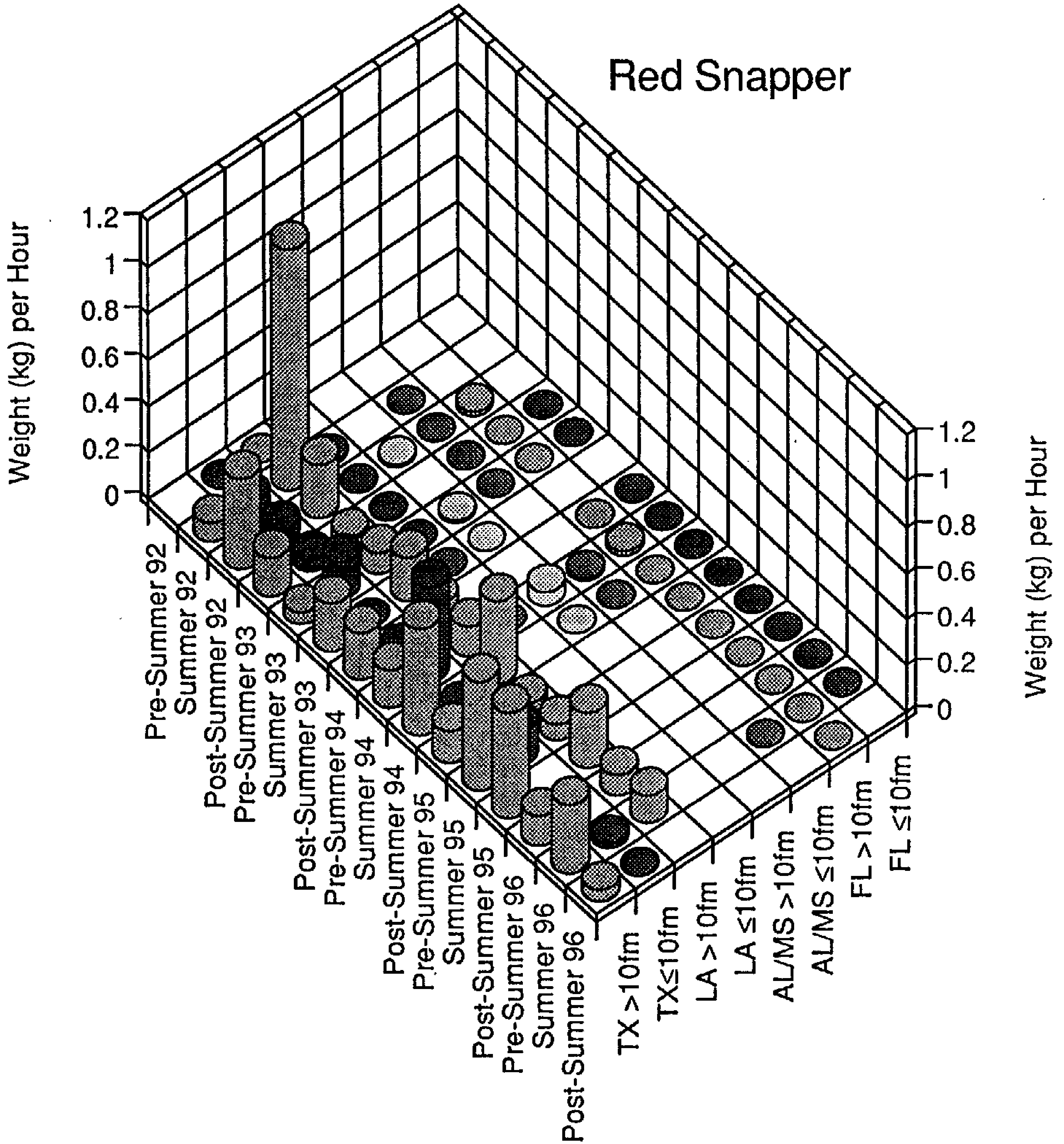


Longspine Porgy
Number per Hour
1200
1000
800
600
400
200
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm

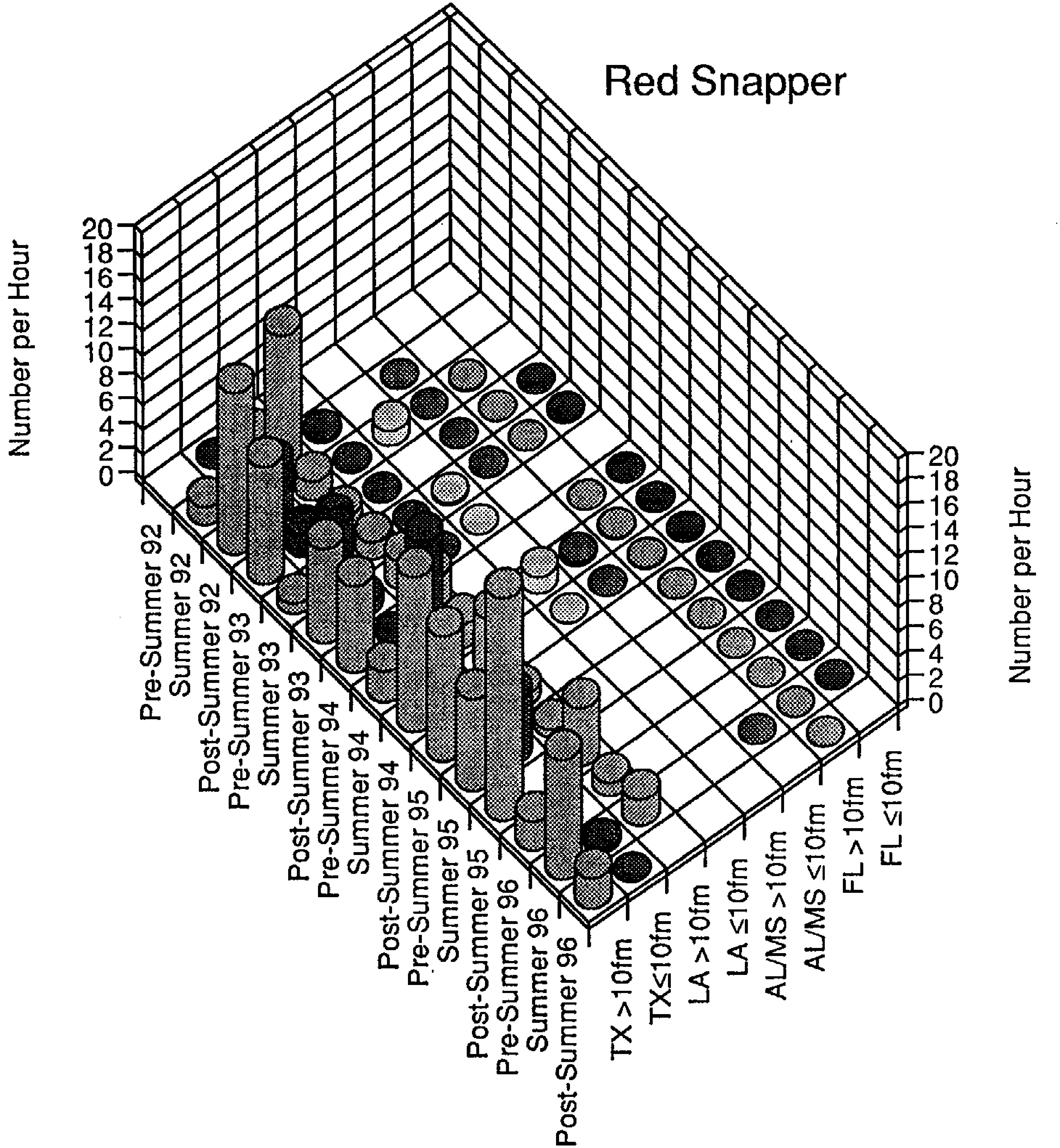

King Mackerel
Weight (kg) per Hour
1.2
1
0.8
0.6
0.4
0.2
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm



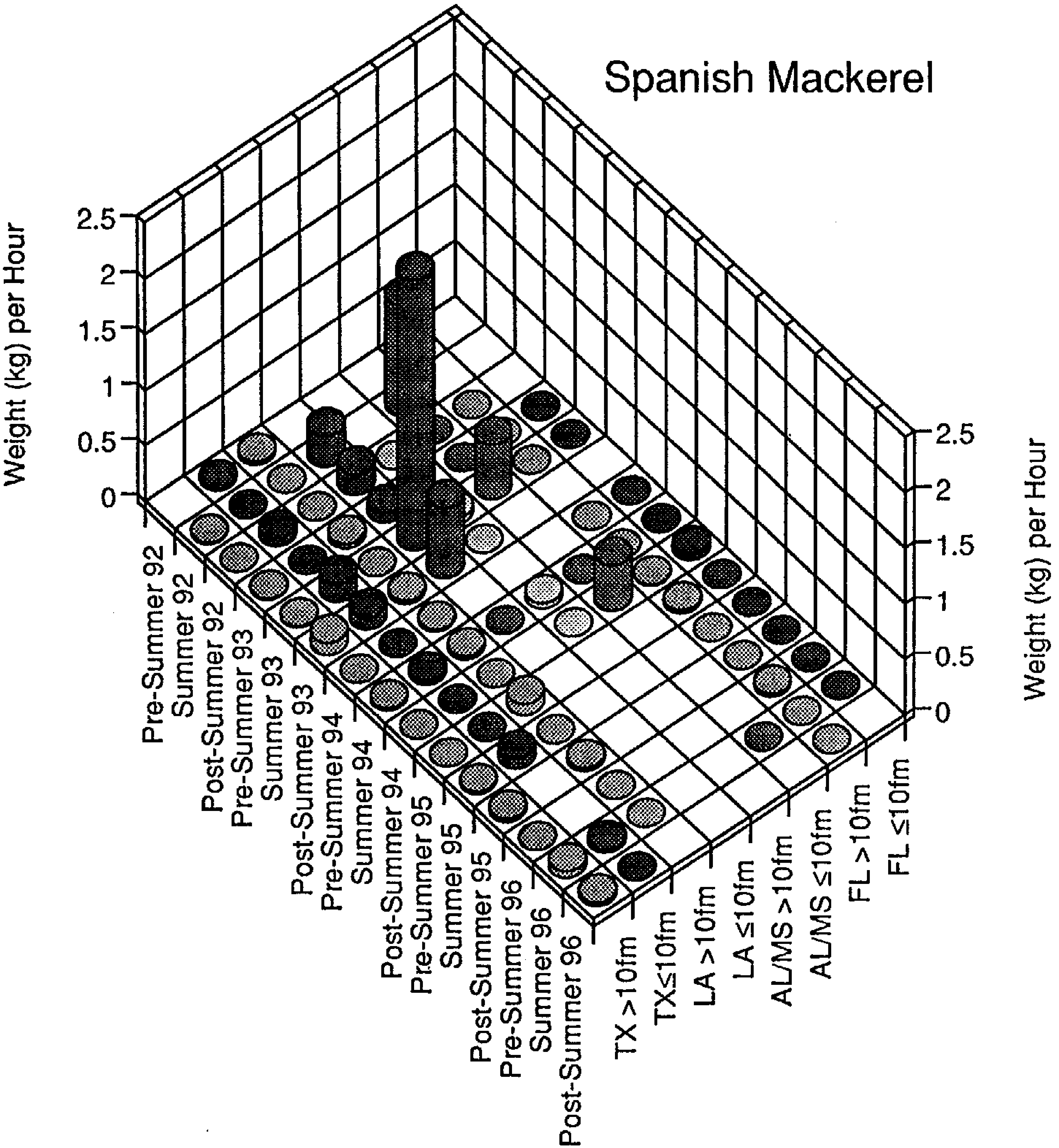
King Mackerel
Number per Hour
0
1
2
3
4
5
6
7
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm



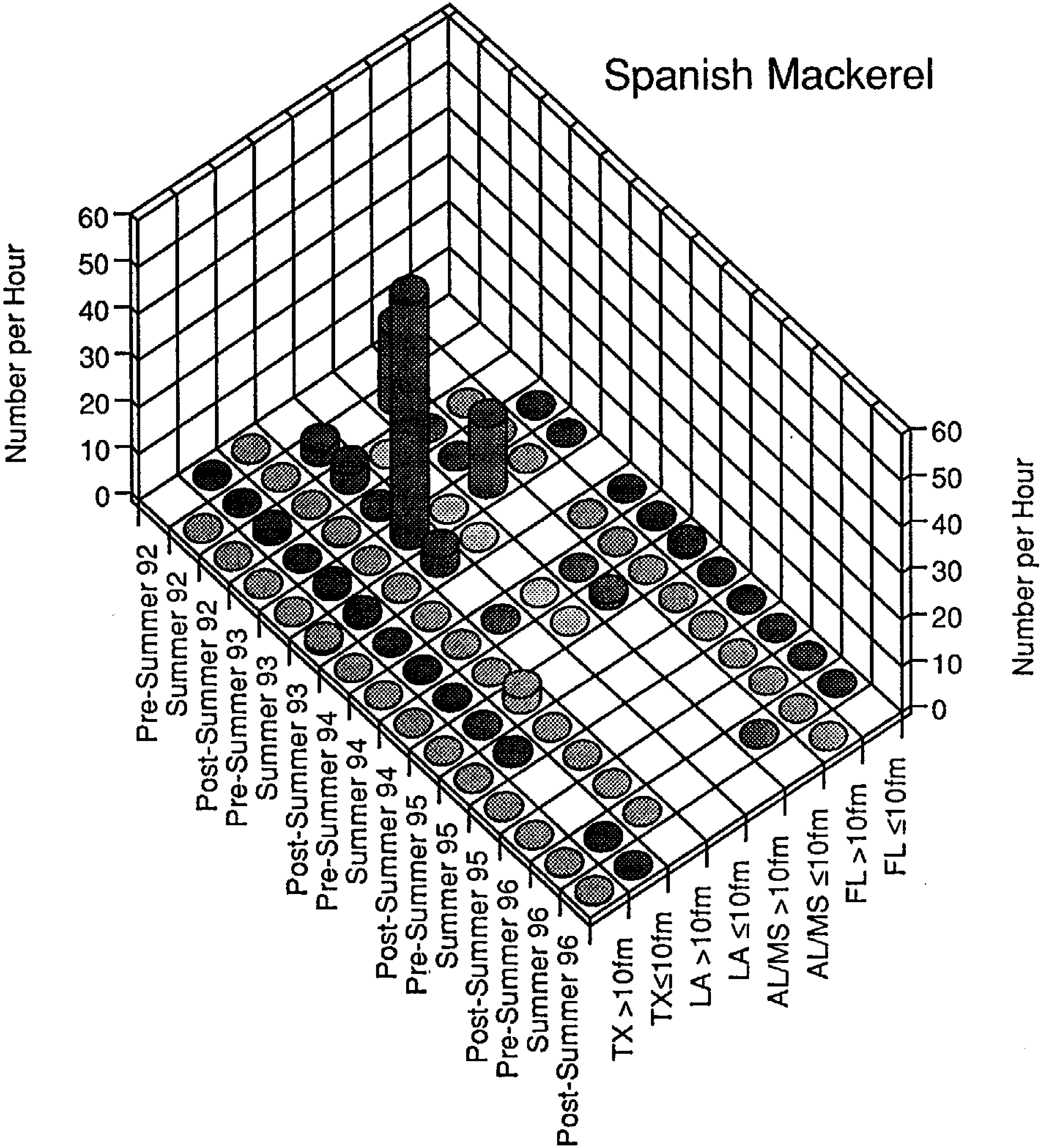
Red Snapper
Weight (kg) per Hour
1.2
1
0.8
0.6
0.4
0.2
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm



Red Snapper
Number per Hour
0
2
4
6
8
10
12
14
16
18
20
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm



Spanish Mackerel
Weight (kg) per Hour
2.5
2
1.5
1
0.5
0
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm


Spanish Mackerel
Number per Hour
0
10
20
30
40
50
60
Pre-Summer 92
Summer 92
Post-Summer 92
Pre-Summer 93
Summer 93
Post-Summer 93
Pre-Summer 94
Summer 94
Post-Summer 94
Pre-Summer 95
Summer 95
Post-Summer 95
Pre-Summer 96
Summer 96
Post-Summer 96
TX >10fm
TX≤10fm
LA >10fm
LA ≤10fm
AL/MS >10fm
AL/MS ≤10fm
FL >10fm
FL ≤10fm

# SECTION 3: BYCATCH REDUCTION DEVICE SUMMARY

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One of the objectives of the bycatch research program is to identify, develop, and evaluate gear options for reducing bycatch in the Gulf and South Atlantic shrimp fisheries (NMFS, 1991). The research program calls for gear modification studies to be conducted in inshore, near shore, and offshore waters focusing on key FMP managed species (i.e., Gulf red snapper, Atlantic weakfish, king mackerel and Spanish mackerel, and coordinated through a technical review panel (TRP). The technical review panel is responsible for selecting the best prototype gear modifications for commercial evaluation, monitoring testing in different shrimping areas, and prioritizing gear modification options for management consideration.

The goal of the gear development project is to develop shrimp trawl gear modifications and or fishing tactics which are capable of reducing the bycatch of finfish with minimum loss of shrimp production. Specific objectives of the program were to evaluate existing bycatch reduction techniques, collect data on behavior of fish and shrimp in trawls, and to develop and evaluate new bycatch reduction techniques. The key species targeted for reduction are red snapper, weakfish, king mackerel and Spanish mackerel.

## METHODS

The research plan (Hoar, P, et al., 1992) identified a four phase gear development program which included:

1. **Initial Design and Prototype Development** - The full technical range of trawl design and modification approaches were identified. Industry techniques, ideas solicited from fishermen, net shops designs, and research studies conducted by various research groups were evaluated. Fish behavior, gear instrumentation, and gear performance studies were conducted on each design using SCUBA, , remote video cameras, and other techniques. This work evaluated fish behavior and feasibility of prototype concepts. The results of this phase were subjectively evaluated based on the experience and expertise of the gear designer and research team. Operational data was taken on the modified net, and preliminary catch performance data obtained during comparative gear trials. The second phase of development was initiated once a design was determined to offer bycatch reduction potential and integrated into the construction of a net.

2. **Proof of concept** - Objectives during this phase were to evaluate prototype devices on key species, determine total finfish reduction rates, and establish shrimp catch rates. Proof of concept testing evaluated adequacy of design for safety and for problems with operational use. Proof of concept testing was conducted under a specific scientific protocol developed under the "Shrimp Trawl Bycatch Research Requirements (NMFS, 1991). The most successful

designs were prioritized based on proportional bycatch reduction and shrimp retention and reviewed by a technical review panel for inclusion in operational evaluation by the commercial shrimping industry throughout the Southeast.

3. **Operational evaluation** - The objective in this phase was to test the BRD/TED gear combination against a standard TED net under conditions encountered during commercial shrimping operations. Trained observers were placed aboard cooperating commercial vessels to collect data on both shrimp and finfish catch rates as well as species composition. BRD/TED combinations were tested on trawlers using the same TED employed in both the test and control gear. Testing was conducted over a wide range of geographic areas, seasons, and conditions.

4. **Industry evaluation** - Widespread commercial evaluations of approved BRD designs.

## RESULTS

A total of one hundred and forty five (145) BRD/TED design combinations have been evaluated under the regional bycatch program between 1990 and 1996. Designs include modified trawl designs, TED designs, fisheye designs, funnel designs, and fish stimulator designs (Watson, et. al., 1993). Proof of concept evaluations have been completed for twenty (21) designs (Table 1). These designs include three different size fisheye BRDs which were tested in four different positions (Appendix I, fig. 1), three funnel designs (Appendix I, fig. 2), a modified funnel design (Appendix I, fig. 3), a modified TED design and a "snake eye" design. The modified TED design was a "Super shooter"(trademark name) TED with holes cut in the side of the extension behind the TED, the "snake eye" design had diamond shaped holes cut in the extension ahead of a Parrish TED. Operational evaluations have been completed for three designs, the top position fisheye design (Appendix I, fig. 4), the expanded mesh design (Appendix I, fig. 5), and the extended funnel design (Appendix I, fig. 6). A fourth design the Davis/Jones BRD (Appendix I, fig 3) has been recommended for operational evaluations.

Operational testing of these designs has been conducted in the Gulf of Mexico on commercial shrimp vessels by the Gulf and South Atlantic Fisheries Development Foundation (Hoar et al., 1992), the National Marine Fisheries Service (NMFS) Galveston and Mississippi Laboratories, Texas Shrimp Association, and Texas A&M Sea Grant and in the South Atlantic by the Foundation, North Carolina Department of Marine Fisheries (NCDMF) and University of Georgia Sea Grant. An extensive data base consisting of over 3,400 tows has been compiled by the NMFS Galveston Laboratory. Analyses of these data were conducted to calculate reduction rate estimates for the different BRD designs for key species which are under existing or proposed management plans including shrimp (weight), red snapper (number), weakfish (number),and Spanish mackerel (number). Reduction rate estimates were also calculated for croaker (weight), spot (weight), and southern flounder (number) which are predominant species or are considered economically important. Data are partitioned by geographical area, South Atlantic statistical zones 29 -36 and Gulf of Mexico statistical zones 8 - 21. Ratio estimation and testing procedures were used for statistical analyses. Data are summarized using point estimates and 95% confidence intervals and are presented in Appendix II, Figures 1 - 52. Upper and lower confidence limits are presented as shaded bars above and below the point estimate, reduction rates which were not significant ($p > 0.05$) are presented as point estimates without shaded bars. Note that non significant negative values are not shown to scale in the graphs in Appendix II. Also note that confidence limits for reduction estimates are not presented in the text, for the precision of the reduction intervals for various BRD designs please refer to Appendices II or III.

Among the BRD designs evaluated, the reduction rate estimates for bycatch varied by species. The best overall reduction rates were demonstrated by, the front position, 12" x 5" fisheye (Appendix II, figs. 45,46,47,48), the extended funnel (Appendix II, figs. 41,42,43,44), the Jones/Davis device (Appendix II, figs. 49,50), and the Andrews TED (Appendix II, figs. 51,52). Among these designs the greatest total fish reduction was demonstrated by the Jones/Davis device (58%) followed by the Andrews TED (57%), the fisheye (37%) and the extended funnel (35%). The lowest reduction in shrimp catch was demonstrated by the extended funnel (0%) followed by the Jones/Davis (4% ns), the fisheye (6%) and the Andrews TED (16%). The best reduction rates for red snapper were 79% for the Andrews TED, and 40% for the Jones/Davis BRD. Snapper reduction rates for the fisheye and the extended funnel were 25% and 20% respectively. Analysis of snapper reduction rates by vessel for these devices indicated the reduction rates for snapper was significantly lower for one vessel when compared to other vessels. Reduction rates for red snapper with this vessel removed from the data set for the fisheye and extended funnel were 51% and 38%. Reduction rate estimates for weakfish were 50% for the extended funnel and 24% for the fisheye. Reduction rate estimates for Spanish Mackerel were 87% for the Jones/Davis BRD, 60% for the Andrews TED, 48% for the extended funnel, and 36% for the fisheye. The best reduction rates for croaker was demonstrated by the Jones/Davis BRD (91%) followed by the Andrews TED (72%), the extended funnel (61%) and the fisheye (57%). Reduction rate estimates for spot were 87% for the Jones/Davis BRD, 60% for the Andrews TED, 54% for the extended funnel, and 41% for the fisheye.

Analysis of data for the 12" x 5" fisheye in the side position (Appendix II, figs. 7,8) resulted in bycatch reduction estimates of 50% for total fish, shrimp reduction of 4% (ns), 93% for croaker, and 83% for spot. The data analysis showed no reduction for red snapper or Spanish mackerel.

Analysis of data for the 12" x 5" fisheye in the offset position resulted in bycatch reduction estimates of 26% for total fish, 1% (ns) for shrimp, 37% for weakfish, 17% for croaker, 15% for spot and 30% for flounder for the South Atlantic area (Appendix II, figs. 27,28) and 33% for total fish, 8% for shrimp, 25% for red snapper, 67% for croaker, and 48% for flounder (Appendix II, figs. 11,12).

Analysis of data for the 4" x 7" fisheye, front position in the South Atlantic (Appendix II, figs. 15,16) resulted in bycatch reduction estimates of 20% for total fish, -1% (ns) for shrimp, 63% for Spanish mackerel and 23% for croaker. Reduction rates for weakfish (1%), spot (22%), and flounder (38%) were not statistically significant. Reduction estimates were 7% for shrimp, and -13% (ns) for total fish, and -9% (ns) for red snapper for the Gulf of Mexico area (Appendix II, figs. 21,22).

Reduction estimates for the 4" x 7" fisheye in the rear position for the Gulf of Mexico area were 4% (ns) for total fish, 0% for shrimp, 22% (ns) for Spanish mackerel, -6% (ns) for croaker, and -25% for spot (Appendix II, figs. 5,6).

Bycatch reduction estimates for the 6"x 6" fisheye in the middle position were 14% (ns) for total fish, 11% (ns) for shrimp, 29% for weakfish, 34% (ns) for Spanish Mackerel, 40% for croaker, 41% for spot, and 51% for flounder (Appendix II, figs. 34,35).

Analysis of data for the 3/5 extended funnel BRD resulted in bycatch reduction estimates of 25% for total fish, 2% (ns) for shrimp, 25% (ns) for red snapper, -19% (ns) for Spanish mackerel, 44% for croaker, 67% for spot and 48% (ns) for flounder (Appendix II, figs. 37,38).

Bycatch reduction estimates for the side opening SS TED were 22% for total fish, 0% for shrimp, 6% (ns) for red snapper, 100% (ns) for Spanish mackerel, 75% for croaker, and 59% for spot (Appendix II, figs. 9,10).

Reduction rate estimates for the Morrison TED were 35% for total fish, 12% for shrimp, 23% for red snapper, 76% for Spanish mackerel, 73% for croaker, and 38% for spot (Appendix II, figs. 1,2).

Estimates of bycatch reduction indicated no significant reduction for any species with the snake eyes BRD (Appendix II, figs. 35, 36).

## DISCUSSION

Shrimp trawl gear modifications have been successfully developed and evaluated under this program for their potential as possible management options to reduce the bycatch mortality associated with shrimp trawling. The 12" x 5" front position fisheye , the extended funnel BRD and the expanded mesh BRD have been approved for use by the shrimp industry in the South Atlantic under Amendment 2 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region (SAFMC, 1996). Technical specifications and minimum requirements for certified BRD designs are presented in Appendix IV. The 12" x 5" fisheye and the Andrews TED have been proposed for implementation in the Gulf of Mexico under Amendment 9 to the Fishery Management Plan for the Shrimp fishery of the Gulf of Mexico (FMP). The results of the current data analyses indicates that the Jones/Davis BRD may also qualify for certification under Amendment 9. The Jones/Davis BRD (Appendix I, figure 3) incorporates a webbing cone behind the funnel which acts as a fish stimulator which may discourage fish from passing into the aft portion of the bag and appears to increase fish reduction rates. This feature appears to be a significant innovation in BRD design technology. Researchers have been experimenting with methods to provide stimulation capable of overriding the optomotor response exhibited by some fish species including juvenile red snapper. The optomotor response is thought to be a deterrent to fish escapement (Watson et al. 1993). The Jones/Davis cone may be a breakthrough in this area of research and more research with this design and other designs incorporating this modification (Appendix I, figures 7,8) may lead to more efficient BRD designs.

**Table 1. Bycatch reduction devices tested under proof of concept protocol ( > 30 tows).**

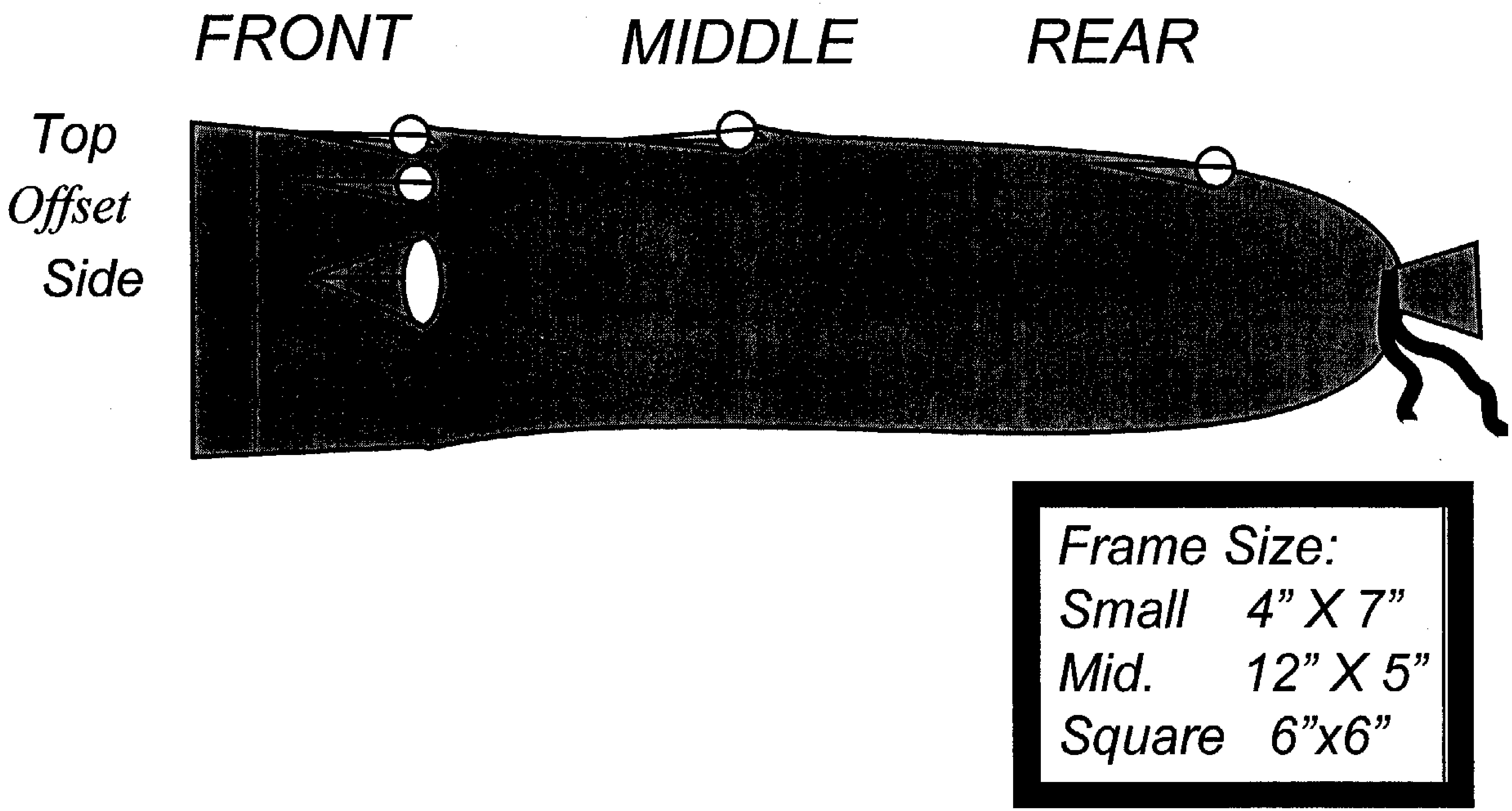
| BRD Type | Area | Number of Tows |
|---|---|---|
| Morrison TED* | Gulf of Mexico | 25 |
| 12x5 Fisheye (Front), SS TED | Gulf of Mexico | 283 |
| 4x7 Fisheye (rear), SS TED | Gulf of Mexico | 46 |
| 12x5 Fisheye (side), SS TED | Gulf of Mexico | 38 |
| Side opening SS TED | Gulf of Mexico | 45 |
| 12x5 Fisheye (offset), SS TED | Gulf of Mexico | 96 |
| Extended Funnel, GA TED | South Atlantic | 52 |
| 4x7 Fisheye (front), GA TED | South Atlantic | 32 |
| 12x5 Fisheye (front), GA TED | Gulf of Mexico | 38 |
| 3/5 Extended Funnel, AW TED | Gulf of Mexico | 65 |
| 4x7 Fisheye (front), AW TED | Gulf of Mexico | 58 |
| Extended Funnel, Burbank TED | South Atlantic | 170 |
| 12x5 Fisheye (front), Burbank TED | South Atlantic | 36 |
| 12x5 Fisheye (offset), Burbank TED | South Atlantic | 55 |
| Extended Funnel, SS TED | South Atlantic | 37 |
| 4x7 Fisheye (front), no TED | South Atlantic | 60 |
| Square Fisheye (middle), no TED | South Atlantic | 30 |
| Snake eyes, Parrish TED | South Atlantic | 34 |
| 3/5 Extended Funnel, Busken TED | Gulf of Mexico | 127 |
| Jones/Davis, SS TED | Gulf of Mexico | 33 |
| Andrews TED | Gulf of Mexico | 34 |

* The Morrison TED data does not meet the 30 tow requirement for certification under the BRD certification protocol but is presented because of the commercial shrimp industry interest in this TED for its potential as a BRD design.

# SECTION 3: APPENDIX I

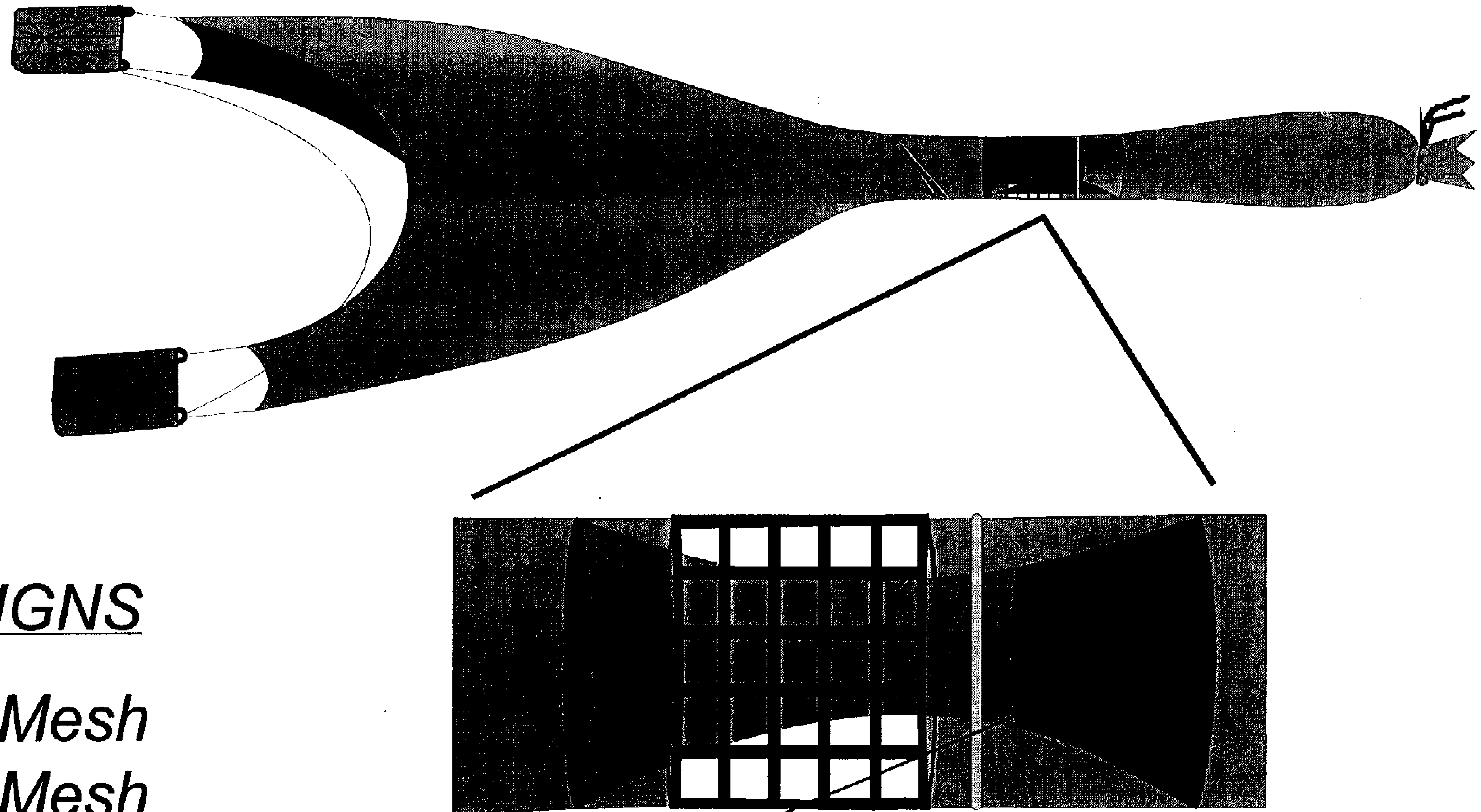
## BYCATCH REDUCTION DEVICE (BRD) DESIGNS

# FISHEYE DESIGNS




Appendix I, Figure 1

# FUNNEL DESIGNS

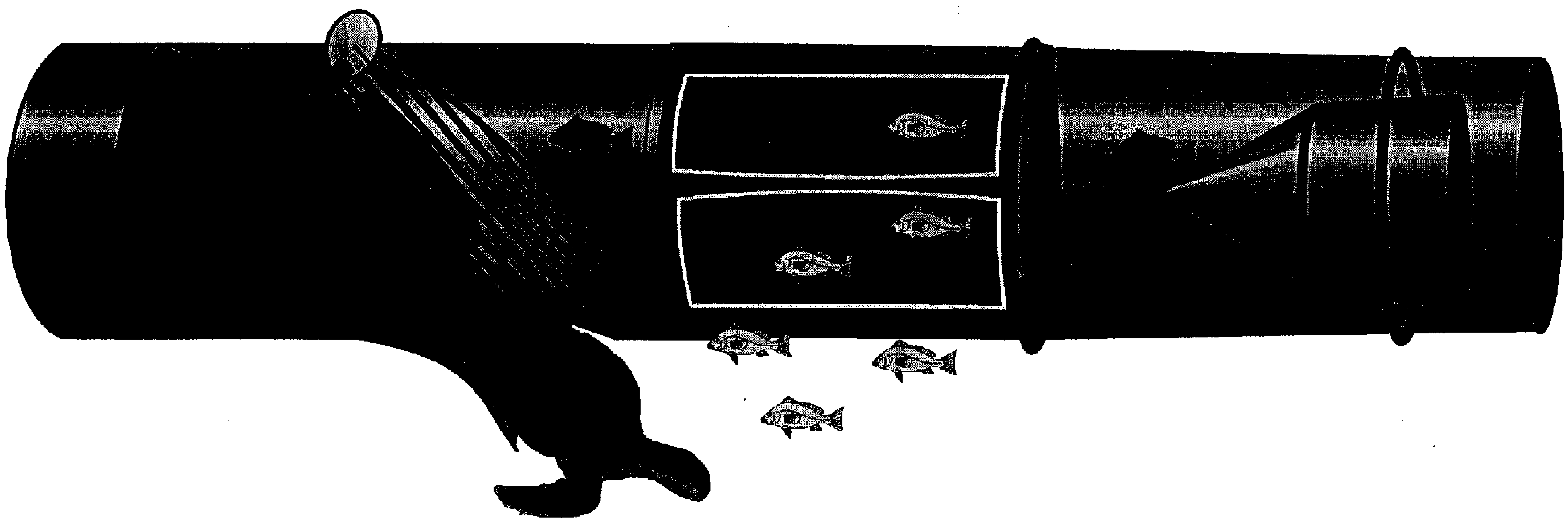


<u>*DESIGNS*</u>

*3 Mesh*
*5 Mesh*
*WITH & WITHOUT EXTENSION*

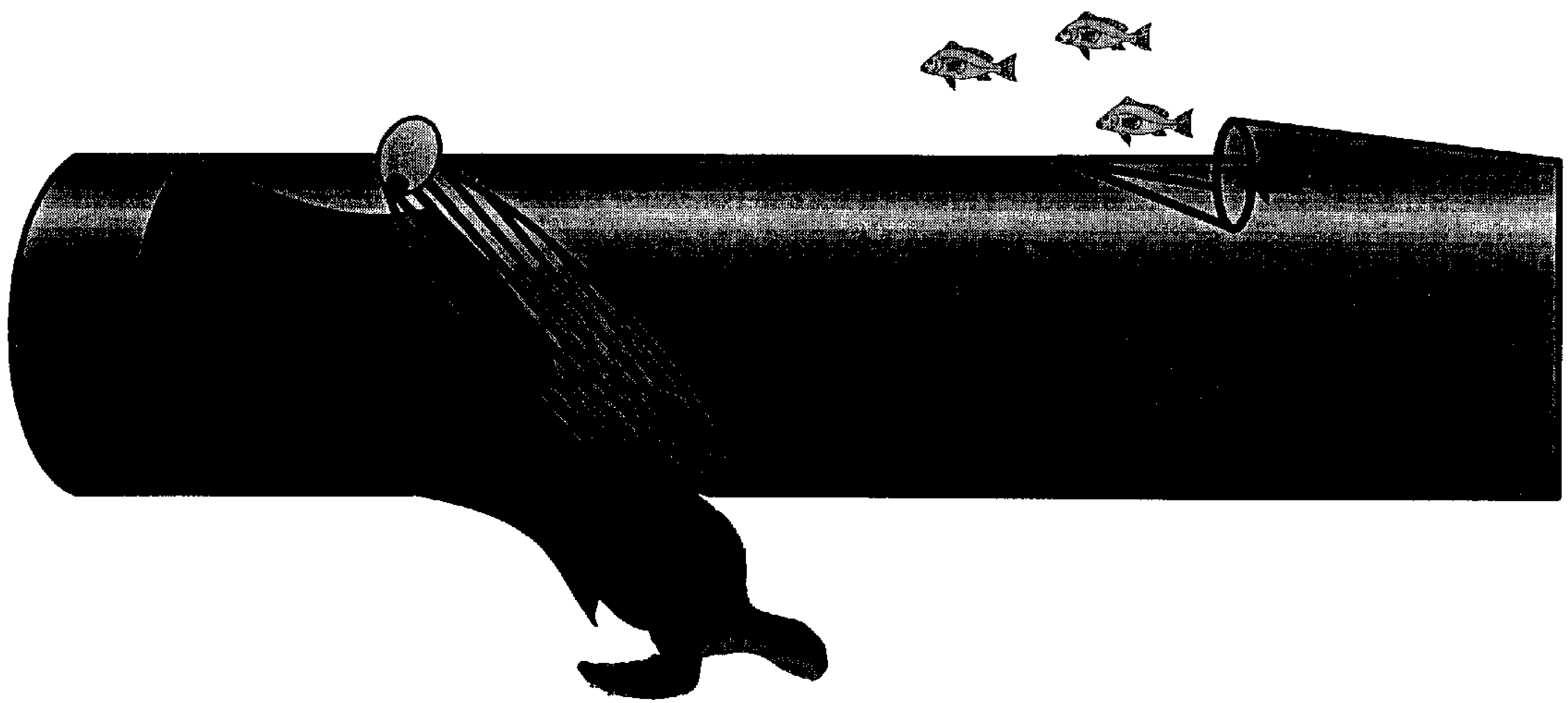
Appendix I, Figure 2

# JONES/DAVIS WITH CONE STIMULATOR



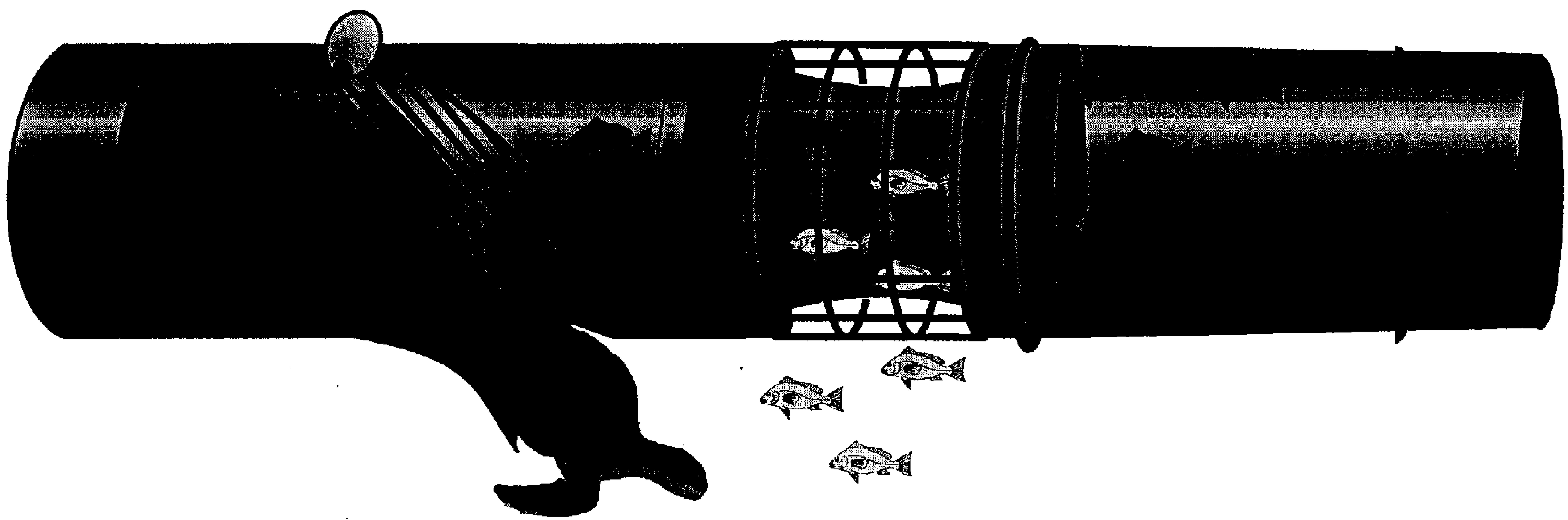
Appendix I, Figure 3

# TOP POSITION FISHEYE



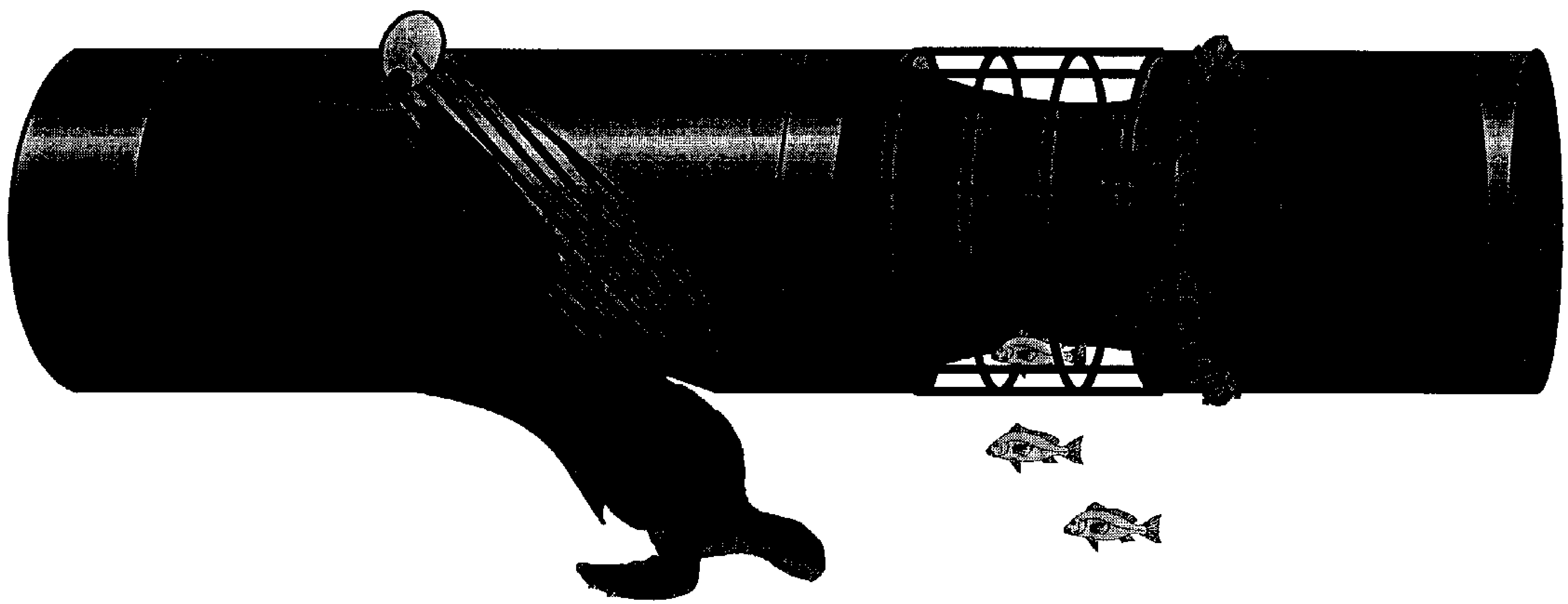
Appendix I, Figure 4

# EXPANDED MESH



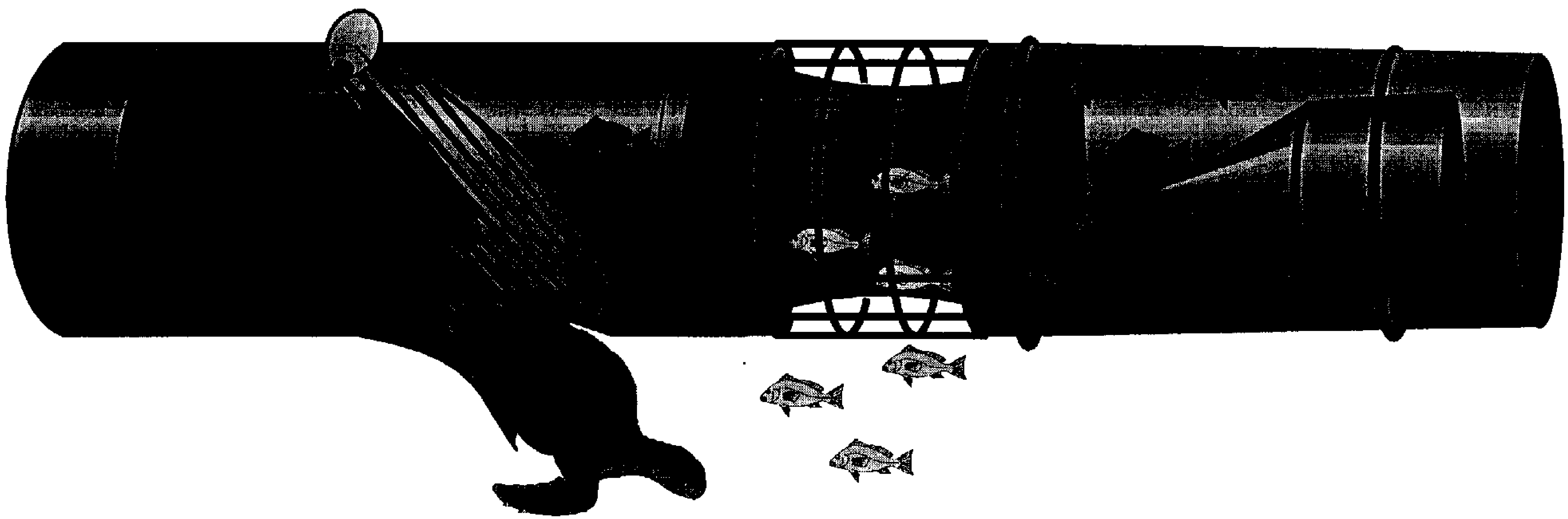
Appendix I, Figure 5

# EXTENDED FUNNEL



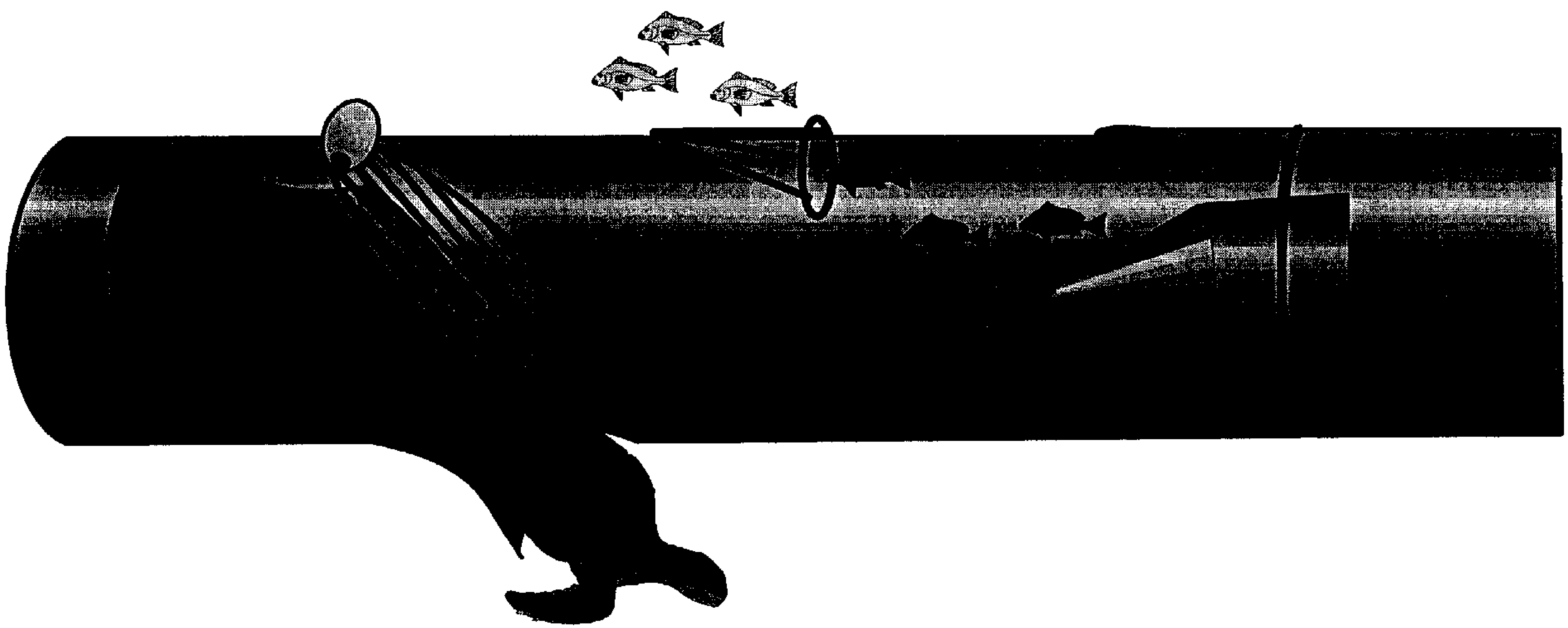
Appendix I, Figure 6

# EXPANDED MESH WITH CONE STIMULATOR



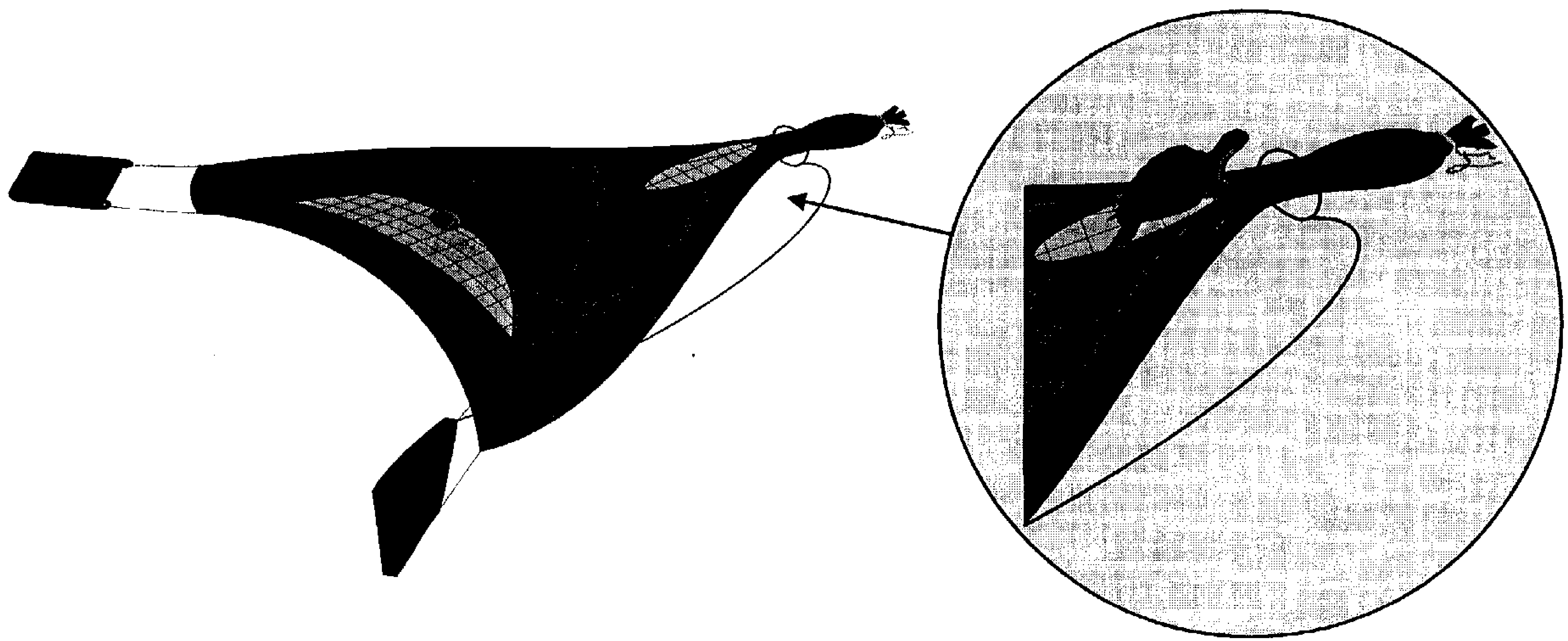
Appendix I, Figure 7

# FISHEYE WITH CONE STIMULATOR



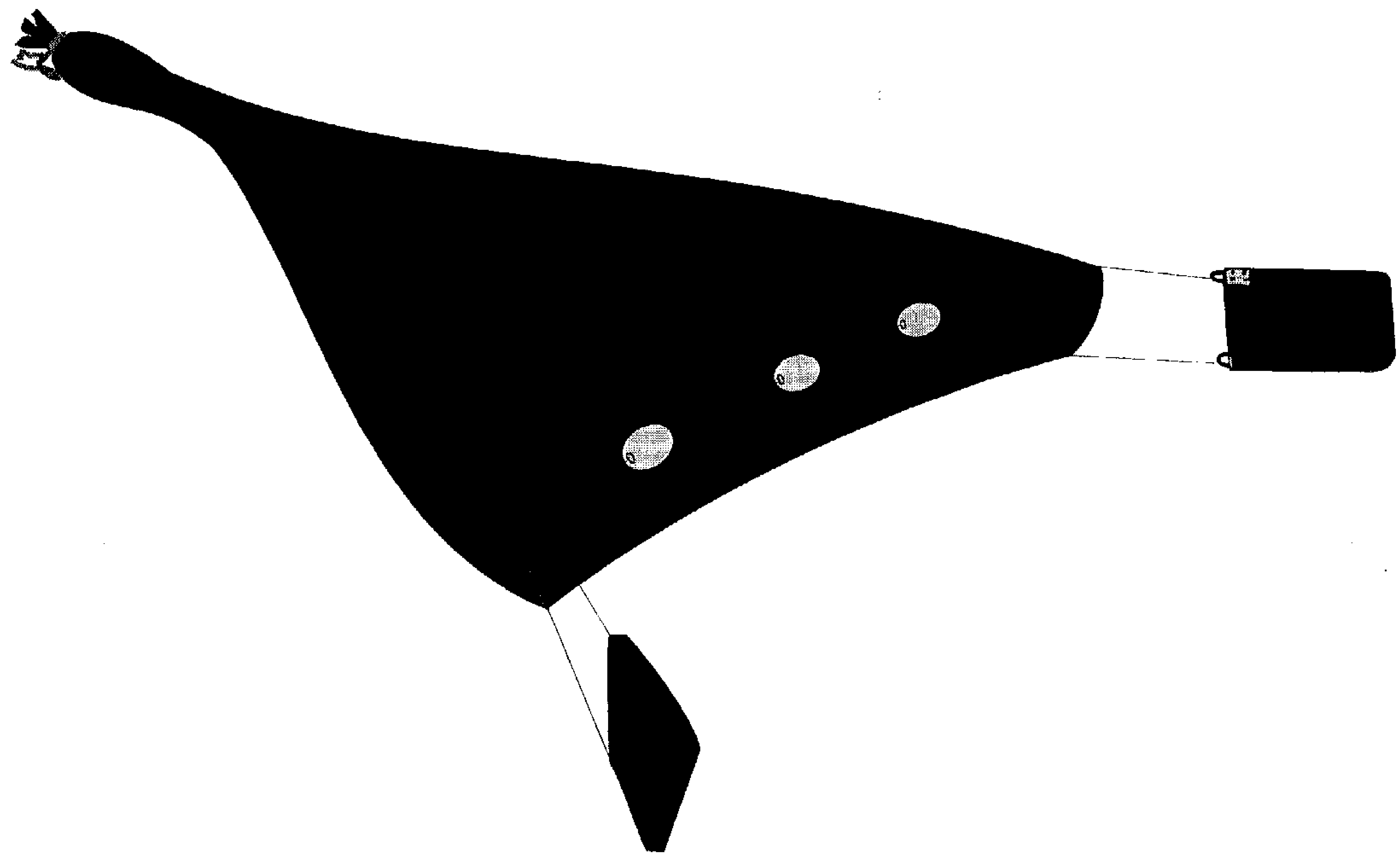
Appendix I, Figure 8

# Morrison TED



Appendix I, Figure 9

# Andrews TED



Appendix I, Figure 10

# SECTION 3: APPENDIX II

## BYCATCH REDUCTION DEVICE (BRD) REDUCTION RATE ESTIMATES